WESSEX WATER'S REPORT TO DEFRA UNDER THE CLIMATE CHANGE ADAPTATION REPORTING DUTY

January 2011

Contents

a YTL company

PART A EXECUTIVE SUMMARY

Questions posed by Defra's Statutory Guidance to Reporting Authorities	Further information in our report
1. Functions impacted by climate change	
a. What are your organisation's functions, mission, aims, and objectives?	1.1 - 1.7
Wessex Water is the regional water and sewage treatment business serving a 10,000 square kilometre area of the south west of England, including Dorset, Somerset, Bristol, most of Wiltshire and parts of Gloucestershire and Hampshire. We aim to provide high quality, sustainable water and environmental services which give customers good service and value for money; protect and improve the environment; provide employees with the opportunity for personal development and a satisfying career; and give our investors a good return on their investment.	
b. Which of these will be affected by the current and possible future impacts of climate change?	1.8 - 1.9; 2.1 - 2.19
All of our functions will be affected by climate change to a greater or lesser degree. This report sets out our assessment of the various climate change-related risks that we face and the adaptation measures that we propose.	
c. Have you assessed the climate thresholds above which climate change and weather events will pose a threat to your organisation? If so what were the main results?	2.16 – 2.18
We have not identified specific climate change thresholds above which particular impacts move from one level of risk to another. For example, we are not in the position to state the temperature increase that would be needed to increase the intensity of storms above the level that could be handled by key sewers or pumping stations. However, we do use certain weather events - such as the 1975-76 drought and 1 in 30 year storms - as benchmarks for action or investment.	
d. Who are your organisation's key stakeholders? Do you need to assess the impacts of climate change on them?	1.6
We have a wide range of stakeholders and an active programme of stakeholder engagement which ensures that constructive two-way communication is maintained. Future impacts of climate change are among the many issues covered.	
2. Approach	
a. What evidence, methods and expertise have you used to evaluate future climate impacts? List sources and references.	2.1 – 2.19
We have drawn on a wide range of evidence including the most recent UK Climate Projections (UKCP09), our long term precipitation record and various assessments carried out by the Environment Agency, regional bodies and consultants on behalf of Government.	
b. How do you quantify, or otherwise estimate or characterise the impact and likelihood of risks occurring at various points in the future?	Sections 3 & 4
We have drawn on various risk assessments, in particular those focused on the water sector and other utilities. We then carried out a risk appraisal, applying our own knowledge to an inventory of water sector risk previously produced for Water UK.	
c. How have you evaluated the costs and benefits of proposed adaptation options?	5.15 – 5.17
We estimated costs and benefits as part of our AMP5 business plan submission to Ofwat. The agreed costs have not been included in this report for reasons of commercial confidentiality.	
3. Summary of risks which affect functions, mission, aims, and objectives	
a. List all the organisations' strategic risks from climate change on a likelihood/consequence matrix – including thresholds where applicable.	Section 4
The full list of risks from climate change, based on the Water UK inventory, is given in appendix 4. The list below covers the highest-scoring risks for our assets and service provision. Detail is provided in section 4.	

Principal water supply risks

Caused by higher temperatures:
- Poorer quality raw water e.g. discolouration and odour caused by growth of algae and other micro-organisms promoted by warmer conditions
- Increasing water demand, reducing security of supply
- More extreme wetting-drying cycles, leading to soil movement & pipe bursts

Caused by drought
- Lower dilution (of contaminants), with risk to drinking water quality
- Lower yields from some sources, increasing demand on other sources / existing storage

Caused by flooding:
- Poorer quality raw & drinking water, due to sedimentation and turbidity
- Direct flooding of water supply assets, leading to service failure
- Loss of power supplies, requiring back-ups to avoid service failure

Principal wastewater risks

Caused by higher temperatures:
- Increased odour from sewage treatment works and sludge
- Greater septicity, affecting the performance of sewage treatment
- Effluent standards tightened due to warmer receiving waters

Caused by drought
- Lower river flows leading to increased risk of tightening discharge standards over time
- Lower flows to sewage works, leading to longer retention in settlement tanks and odour problems
- Sedimentation in sewerage causing blockages, leading to sewer flooding, spills from combined sewers and pressure on treatment works

Caused by flooding
- Flooding of properties as combined sewers and surface water sewers are overwhelmed
- Capacity of pumps and / or combined sewers exceeded, leading to spills that reduce receiving water quality
- Groundwater infiltration into sewers, leading to sewer flooding
- Direct flooding of sewage treatment works / critical pumping stations
- Flooding of transport routes and waterlogging of fields, affecting sludge recycling operations

Caused by sea level rise / coastal flooding
- Combined sewers at full capacity during high tides, leading to customer flooding and discharges reducing water quality
- Direct loss of assets, particularly if coastal realignment was required

b. What short and long term impacts of climate change have you identified and how are each factored into the adaptation programme? Quantify the likelihood and consequences as far as possible (including an assessment of the level of confidence (e.g. high/medium/low) in the calculations) and disaggregate these risks to different locations where appropriate	2.3 – 2.4; 2.10 – 2.19; 3.5 – 3.8; section 4

On the basis of UKCP09, in the short term (to the end of the 2020s) we expect our region to experience 0%-10% less average summer precipitation; 0% – 10% more average winter precipitation; and intense flooding events at any time. As well as the risk assessment carried out for our climate change adaptation plan, these values are being incorporated into planning of water resource management and sewerage design.

In the longer term (2040 and beyond) the central case in UKCP09 suggests up to 30% less summer rainfall; up to 20% more winter rainfall; and reduction in the return period of the most intense storm events. Along our Severn Estuary coastline, we could see 2 metre increases in the combination of sea level rise and 1 in 50 year storm events. We have not quantified an overall risk score for each of these general climate change impacts; instead, we have scored each of the associated impacts on assets and services using Water UK's adaptation inventory.

c. What are your high priority climate related risks and why (stating level of impact to business, likelihood, costs and timescales)?	Section 4

See 3a.

d. What opportunities due to the effects of climate change which can be exploited, have been found?	4.7

Milder winters would help some sewage treatment processes; warmer conditions could reduce heating costs and increased winter rainfall would mean earlier recharge and reservoir filling.

4. Actions proposed to address risks

a. What are the adaptation actions for the top priority risks (stating timescales)?	Section 5, summarised in tables 8, 9, and 10

Much of our long-standing work helps us to build resilience to change, including climatic changes. Examples include water resource planning, water demand management and maintenance of our sewerage network. However, only a small part is recognised explicitly by our regulator Ofwat as climate change adaptation, with funding for work agreed by them via our five-year business plans. We describe this as 'instructed adaptation' and during the next five years there will be three funded projects focusing on flood protection measures at a sewage pumping station and two water treatment works. The other work that we will be carrying out for various reasons, which also benefits our adaptability in the medium to long term, we describe as 'complimentary adaptation'.

b. How will the adaptation actions be implemented (stating level of responsibility, investment and timescales)?	5.7 – 5.14

Actions will be implemented in the same manner as other investments. In most cases, the timescale for delivery will be the five year investment plan agreed with regulators, although planning over longer timescales is brought to bear, such as the 25 year Water Resources Management Plans. Scheme options are discussed internally with solutions signed-off by senior managers, liaising where needed with regulators and other third parties. Where building work is required, work is allocated to construction partners. We report annually to our regulators on our progress in implementing our investment programme, as well as other measures designed to achieve our objectives.

c. How much do you expect these adaptation measures to cost and what benefits do you anticipate will result from them?	5.15 – 5.17

We assessed costs and benefits as part of our AMP5 business plan submission to Ofwat. The principal benefits for the 'instructed adaptation projects' are reduction of the risk of disruption from flooding. Other 'complimentary adaptation' work provides headroom and increases our ability to provide expected standards of service in the face of more extreme weather events. The agreed costs for 2010-15 have not been included in this report for reasons of commercial confidentiality.

d. How much do you expect them to reduce risk by, and on what timescales?	5.18 – 5.19

The risk assessment scores shown in this report are for *current* levels of risk. In all cases, we aim to reduce risk to an acceptable level, such that we can continue to provide expected levels of service, even if in some acute cases we have to make a focused effort and deploy extra resources to do so. Mitigation work will reduce risk at sites where investment has been agreed, typically during the five year timescale of our regulated investment programme.

e. How will you ensure the management of climate change risks is embedded in your organisation?	Section 6

The climate change adaptation plan presented here has been approved by Wessex Water's senior managers, our Board of directors and our Sustainability Panel. We will maintain high-level visibility of the issues involved through updates and papers on an annual basis. Climate change risks are embedded at a technical level mainly through managers who are building climate projections – particularly concerning rainfall – into our asset planning and management. We will iteratively develop our risk assessments and working practices (such as flow modelling) as knowledge develops and climate projections are updated.

5. Uncertainties and assumptions

a. What are the main uncertainties in the evidence, approach and method used in the adaptation programme and in the operation of your organisation?	2.14 – 2.16

We can not know exactly the extent to which projected changes will play out in any given location, year or season. While there is good confidence in the main direction of change over the 21st century, the pace of change is uncertain. For our part, we are not able to narrow down our own projections using modelling; rather our work is based on UKCP outputs. We also acknowledge that while our risk assessments have been conducted in a structured manner, there are elements of uncertainty and subjective judgements involved.

b. What assumptions have been made when devising the programme for adaptation?	2.3, section 3

Our risk assessments for our overall plan were based on the central case, in probability terms, presented by UKCP. This provides a single projection for rainfall during the period labelled as the 2020s (2010-2039), regardless of the emissions scenario used. These dates also encompass the time horizon of our water resources management plan.

6. Barriers to adaptation and interdependencies

a. What are the barriers to implementing your organisation's adaptation programme? b. How will these barriers be addressed?	6.11 – 6.12

The main potential barriers to climate change adaptation are technical, regulatory, and financial. These include the cost of adaptation measures; competing demands for investment in public goods; the timing of climate projections in relation to investment decisions; uncertainty about the pace and scale of change and other limits to knowledge; and delays caused by complexity. Combined, these can lead to a very cautious approach to adaptation measures on the part of Government, regulators, water companies themselves and other interests.

c. What / who are the interdependencies (including the stakeholders stated in response to question 1d)?	6.7 – 6.10

Our most notable interdependencies are with climate modellers, regulators, customers (both domestic and commercial / industrial), the media, other utility providers, suppliers and contractors, other water companies and organisations involved in surface water management such as local authorities, internal drainage boards and the Highways Agency.

7. Monitoring and evaluation

a. How will the outcome of the adaptation programme be monitored?	6.4

As a matter of course we will monitor both our 'instructed' and 'complimentary' adaptation measures. In some cases, the success of the work carried out will not be immediately obvious; in the case of flood risk mitigation work for example, we might wait many years for the scale of event to occur for which the investment was designed and implemented. Other measures, such as water efficiency work, involve more gradual change but are part and parcel of the monitoring work we carry out anyway.

b. How will the thresholds, above which climate change impacts will pose a risk to your organisation, be monitored and incorporated into future risk assessments?	2.14 – 2.16

We will continue to review impacts on our service provision during extreme weather events while building UK climate projections into our risk assessments and planning activities. We will also listen to any guidance on how and when to use the more extreme projections e.g. those modelling 90% percentile (very unlikely) impacts under the high emissions scenario.

c. How will the residual risks of impacts from climate change on your organisation and stakeholders be monitored?	5.18 – 5.19; 6.4

While we will be open to any feedback that we receive on our risk assessments as published in this report, we propose to revisit this exercise following the publication of the next round of UK Climate Projections. We will also review the residual risks that are scored highest in the preparation of our business plan for 2015-20.

d. How will you ensure that the management of climate change risks is firmly embedded in your organisation?	Section 6

See 4e.

e. How will you enable your management of climate change risk to be flexible?	6.6

Our adaptation plan and management of climate change risk will not be fixed in perpetuity. Although we can set out preferred approaches, we must be flexible as new data emerges or risk assessments change. This applies to our water supply and waste water activities alike.

f. Has the production of this report led to a change in your management of climate risks?	7.2

Production of this report will contribute mainly to our communication – both internal and external - of climate change risks and the measures we propose in our adaptation plan.

Part B. MAIN REPORT

1. Overview of Wessex Water and potential climate impacts

Wessex Water's mission, aims, objectives and functions

1.1. Wessex Water is the regional water and sewage treatment business serving a 10,000 square kilometre area of the south west of England, including Dorset, Somerset, Bristol, most of Wiltshire and parts of Gloucestershire and Hampshire.

1.2. YTL Power International of Malaysia acquired Wessex Water in May 2002. YTL's demonstration of its long term commitment to Wessex Water has provided stability and certainty to the business, and enabled us to continue to provide a first class service to our customers.

1.3. Wessex Water aims to provide high quality, sustainable water and environmental services which:

- give customers good service and value for money
- protect and improve the environment
- provide employees with the opportunity for personal development and a satisfying career
- give our investors a good return on their investment.

Wessex Water is recognised by the water industry regulator, Ofwat, as one of the most efficient and highest performing water and sewerage companies in England and Wales.

1.4. Table 1 below outlines the assets that are currently deployed to meet our principal water supply and sewerage functions. The performance of these assets is influenced by a range of factors including, but by no means limited to, the climate in which we operate and the weather events that we experience.

Table 1. Overview of our asset base

Water supply	Sewerage services
350 million litres of water supplied each day to 1.3 million customers, via: 97 water sources 110 water treatment works 209 booster pumping stations 344 service reservoirs and water towers 11,478 kilometres of water mains	481 million litres of sewage treated each day from 2.7 million customers, via: 17,300 kilometres of sewers 405 sewage treatment works 1,003 combined sewer overflows 1,438 pumping stations

1.5. We have a wide range of stakeholders, notably:

- Domestic customers
- Commercial & industrial customers
- Other water users
- YTL Utilities (owner of Wessex Water)
- Other investors
- Regulators
- The media
- Suppliers and contractors
- Wessex Water employees
- Other organisations involved in water management (e.g. local authorities)
- Farmers and landowners
- Local communities
- Interest groups (e.g. wildlife organisations)

We have an active programme of stakeholder engagement which ensures that constructive two-way communication is maintained. Future impacts of climate change are among the many issues covered.

1.6. Wessex Water's Sustainability Vision is a statement of what would constitute a genuinely sustainable water company, in terms of our impacts on the environment, our stakeholders and our staff, as well as the condition of our assets and our financial position. Wessex Water's commitment to adapt to climate change is summarised in the Sustainability Vision as "Being in a position to adapt to weather events caused by climate change, without harming levels of services and standards". This was reinforced in our 2007 Strategic Direction Statement, in which we stated that part of operating and maintaining the condition and capacity of our assets to the highest possible standards for future generations was the need to ensure they are capable of dealing with the effects of climate change. We see climate change as one of the most important factors affecting our resilience over the long term.

Current and possible future impacts of climate change on functions, mission, aims, and objectives

1.7. As our day-to-day services and operations are affected by weather patterns, climate change needs to be accounted for in our long term planning. Thus, the predicted drier summers, wetter winters and increased storminess as a consequence of a climate change will have a bearing on all our activities. Table 2 below provides a high level view of possible climate change impacts on our activities for which we have assessed medium or high levels of risk. Sections 2 to 4 and the appendices give more detail.

1.8. This report sets out the climate change hazards that we recognise, the level of risk that each poses for our business and the adaptation options that we have in place or propose. The associated plan has been reviewed by Wessex Water's senior management team, our Sustainability Panel, and the Board of Wessex Water Services Ltd. The sections that follow outline the work we are undertaking to embed this plan and implement it, with general discussion of organisational issues in section 6.

Table 2. Headline risks

Water supply	Sewerage services
Water resources • Lower yields from sources • Higher demands caused by hot conditions, affecting security of supply • Damage to supply pipes and water mains due to more extreme wetting / drying cycles ***Water quality*** • Reduced raw water quality due to warm, dry weather (e.g. algal blooms) and storminess (contaminants from run-off) ***Water supply assets*** • Flooding of assets or of power supplies serving them	***Sewerage*** • Sewer flooding with more intense rainfall events; flooding return periods becoming shorter • Detriment to water quality as combined sewers spill or pumps fail during storm conditions • Sewer flooding of properties in low lying coastal areas where drainage is compromised by high tides and rising sea levels ***Sewage treatment & sludge*** • Warm and dry weather causing increased odour from sewage treatment works & sludge; and more septicity at treatment works • Tighter standards for treating effluent due to warmer conditions and lower flows in receiving waters • Limited access to fields during prolonged wet weather where sludge is reused ***Sewerage & sewage treatment assets*** • Flooding of assets or of power supplies serving them; loss of coastal assets with sea level rise

2. The evidence base: historic weather and projections for future climate change

Overview

2.1. This section provides an overview of the evidence of climatic change worldwide, in the region in which we operate and for water utilities in general.

The global picture

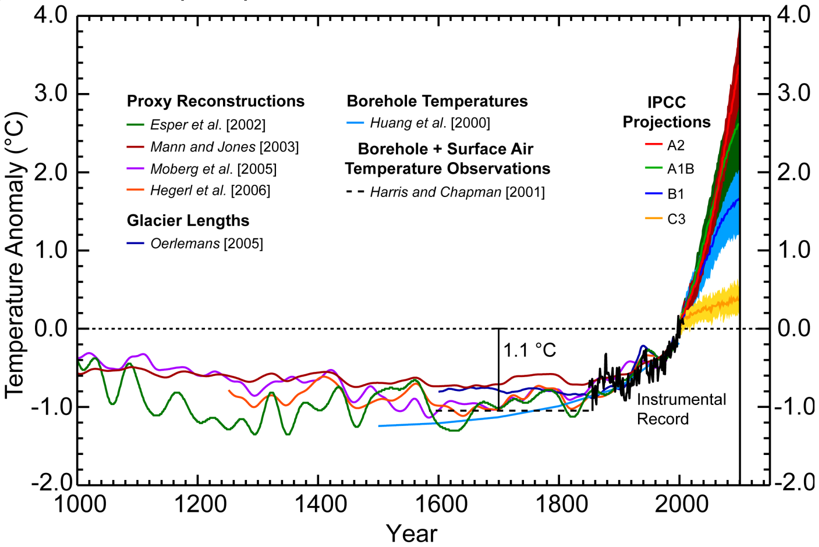
2.2. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change, produced in 2007, is the most recent comprehensive overview of the scientific basis of climate change, potential impacts and options for limiting concentrations of greenhouse gases in the atmosphere. Its headline conclusions include the following:

- *"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level"*. There has been a recorded increase in global average temperature of 0.74°c in the last 100 years.

- *"Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations"*. The term 'very likely' means that the assessed likelihood using expert judgement is more than 90%. In 2010, the concentration of carbon dioxide was 390 parts per million (ppm), greatly exceeding the range of the last 650,000 years (180-300ppm).

- The likely consequence of atmospheric carbon dioxide concentrations doubling from pre-industrial levels, would be an increase in global average temperatures in the range of 2°c – 4.5°c, with the best estimate being a 3°c increase. As figure 1 below shows, all IPCC projections show that global average temperature by the end of the 21st century will exceed reconstructions of temperature during the last 1,000 years.

Figure 1. Reconstructions, records and projections of the Earth's surface temperature, from Chapman & Davis (2010)



Earth's surface temperature past, present and future *from* Chapman, David S., and Davis, Michael G., 2010; Climate Change: Past, Present, and Future; *Eos Transactions of the American Geophysical Union*, v. **91** (37), 325 – 326.

UK Climate Projections

2.3. Like other water companies, we have been engaged in the development of the last two rounds of UK Climate Projections (UKCIP02 and UKCP09) and have applied their outputs. In the latest version, released in 2009, projections for individual 25km squares incorporate the following dimensions:

- three different emissions scenario (high, medium, low)
- three time periods of the 21st century (2020s, 2050s and 2080s)
- varying probability, based on evidence for different levels of future climate change.

2.4. Appendix 1 provides some detail from UKCP09 projections for the Wessex Water region for four key indicators: winter rainfall, summer rainfall, annual average daily temperature, summer mean temperature and sea level rise. The projected changes are in comparison with the period 1961-1990. Headlines for our region under the most likely 'central case' are shown in table 3. Clearly, changes to winter and summer precipitation are expected to be much more marked than changes to average rainfall across the year as a whole.

Table 3. Overview of UKCP09 projections

	2020s	2050s	2080s
Annual mean precipitation	0 to +10%	-10 to +10%	0 to +10%
Summer (Jun-Aug) precipitation	0 to -10%	-10% to -30%	- 10% to -40% [1] - 20% to -50% [2]
Winter (Dec-Feb) precipitation	0 to +10%	+10 to +20%	+20% to +30% [3] +10% to +20% [4]
Spring & autumn precipitation	0°c to +10%	0°c to +10%	0°c to +10%
Annual average temperature	+1°c to +2 °c	+2°c to +3 °c	+2°c to +5°c [1]
Summer mean temperature	+1°c to +2 °c	+2°c to +4 °c	+3°c to +6°c [1]
Summer mean maximum temperature	+2°c to +3 °c	+3°c to +5°c [1]	+3°c to +7°c [1]
Warmest day of summer	0°c to +2 °c	+2°c to +4 °c	+2°c to +6 °c [1]

[1] Variation depends on the emission scenario used (i.e. higher variation under high emissions scenario)
[2,4] Driest part of the region; range reflects different emissions scenarios
[3] Wettest part of the region

Wessex Water's rainfall records

2.5. Wessex Water's records of monthly rainfall since 1931 (measured by the Environment Agency at gauges spread across our region) allow us to take a long term historic view; for example, comparing droughts and prolonged wet weather against averages. They also allow us to compare *projected* changes in precipitation caused by climate change with *actual* variability in recent years.

2.6. Precipitation data from our records are shown in the graphs below. Figure 2 shows average monthly rainfall over two periods: 1931-32 to 2009-10 (being the full extent of our records) and the 1961-1990 reference period used by UKCP. The annual average is 854mm for 1931-32 to 2009-10 and 838mm for 1961-1990. The graphs that follow plot annual values and seasonal rainfall in the three month blocks identified by UKCIP as spring, summer, autumn and winter, with 20 year moving averages from 1951 onwards.

Figure 2 **Average monthly precipitation**

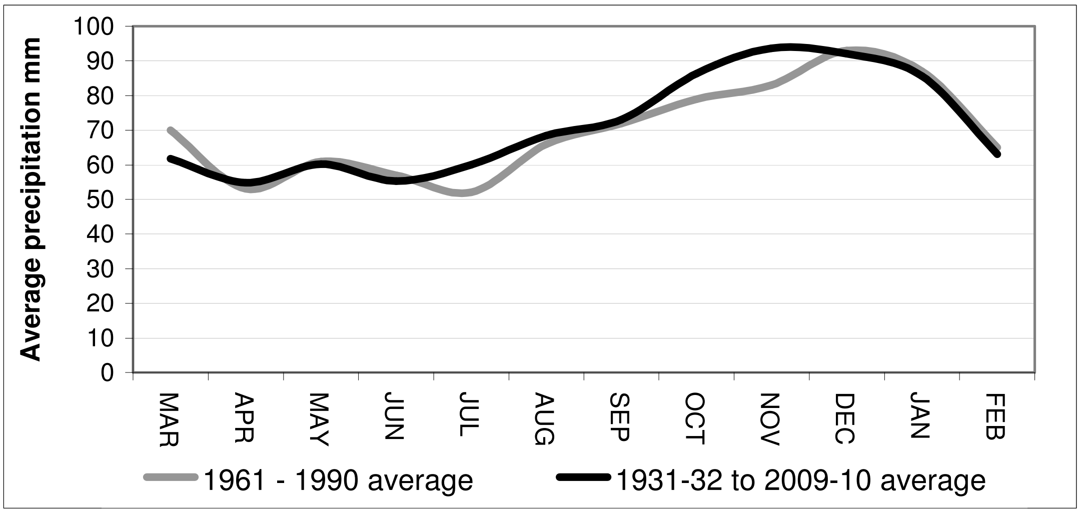
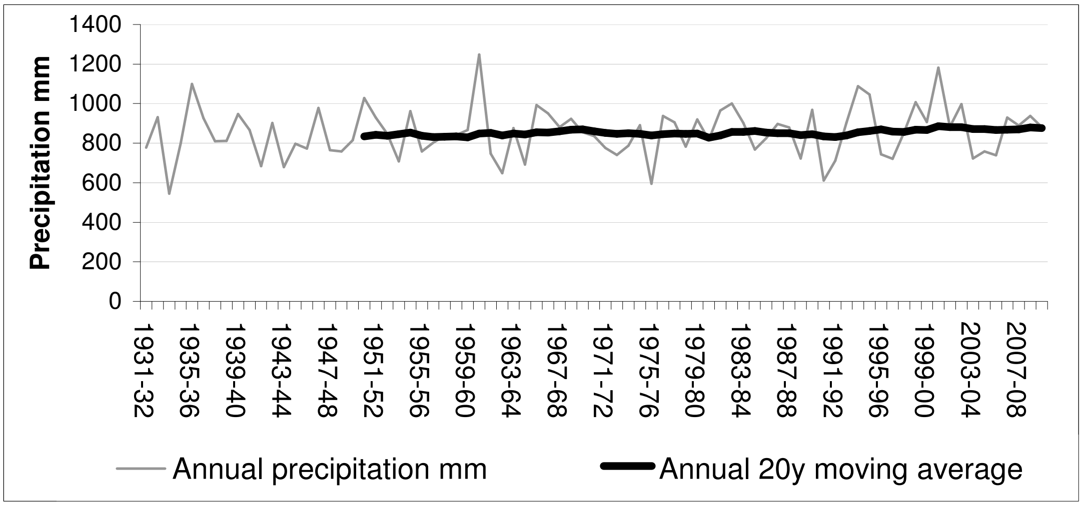
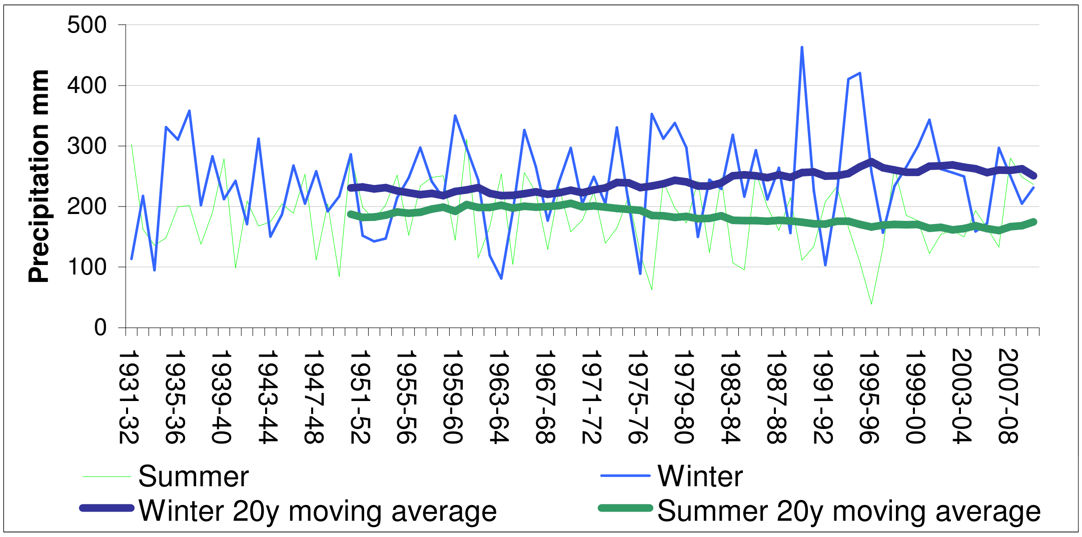
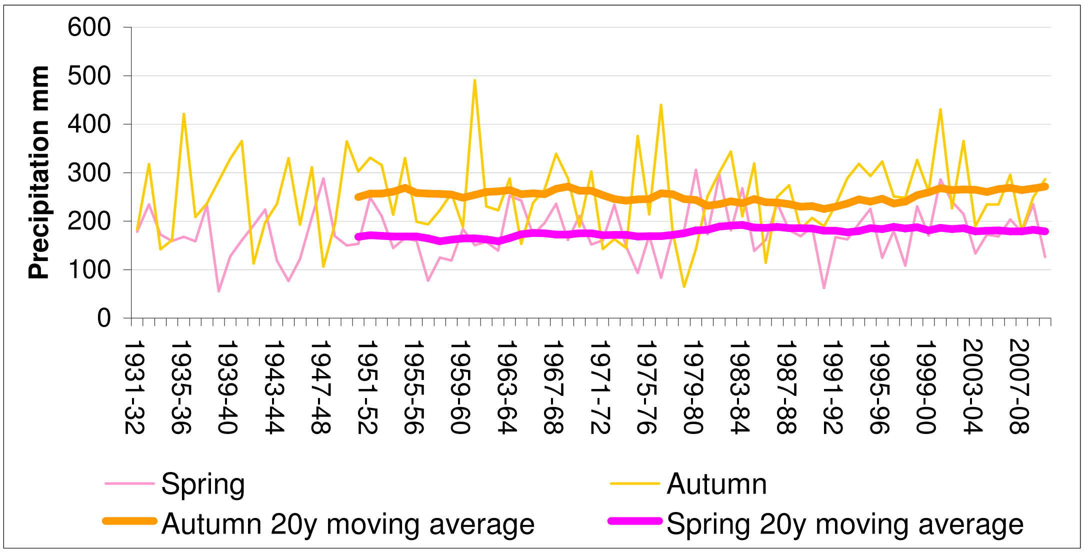


Figure 3 **Historic precipitation data from Wessex Water's records (mm)**

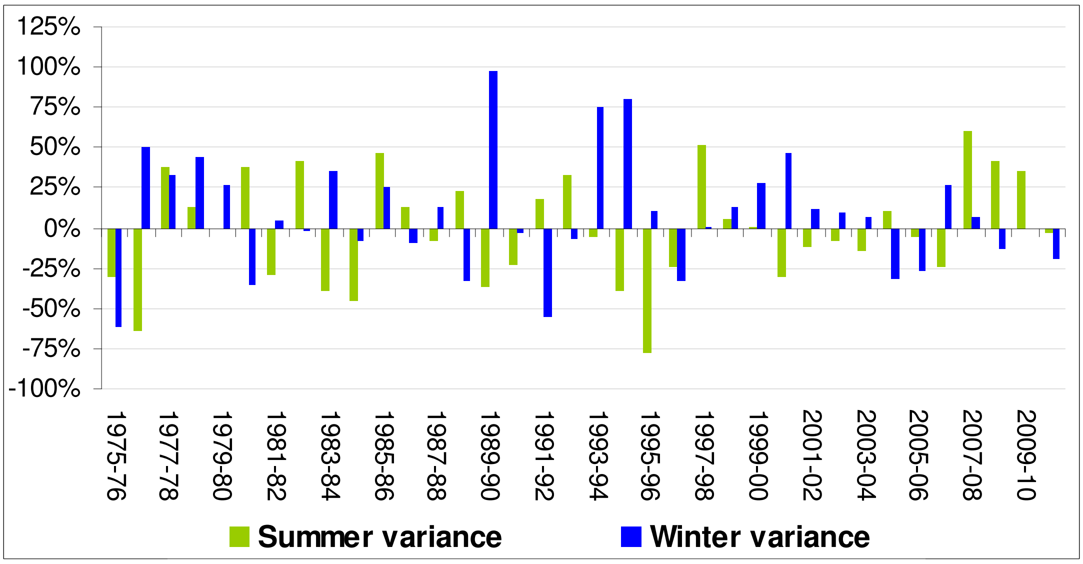






2.7. Figure 4 shows the variance in summer and winter precipitation over the last 35 years compared with the UKCP reference period.

Figure 4. Variance against 1961-1990 average winter & summer rainfall

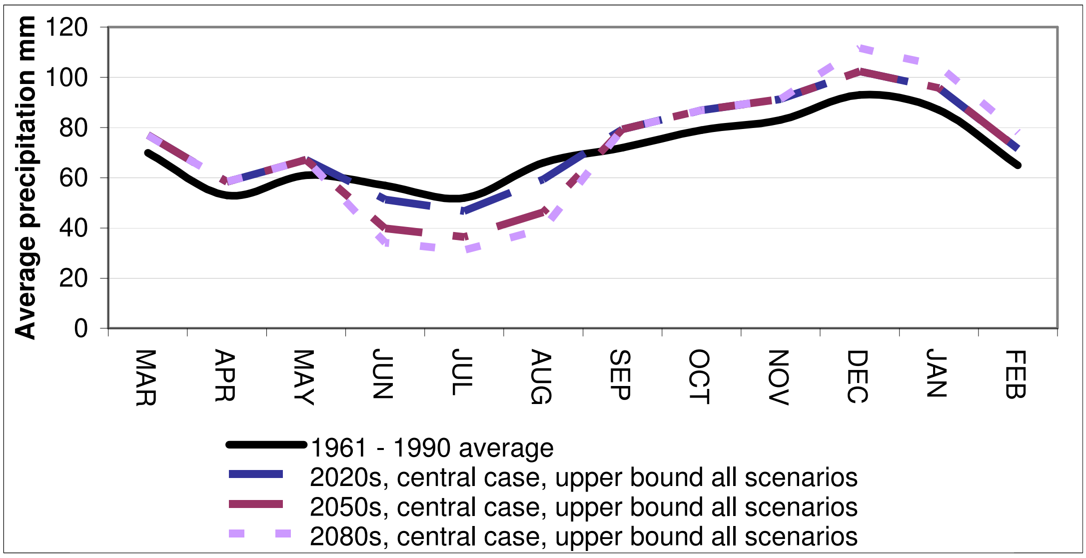


2.8. In the context of climate change and resilience, our historic record provides a few noteworthy points. Firstly, average annual precipitation was broadly level over the last sixty years. Secondly, from the 1970s to around 2005 there was a slight increase in winter rainfall and a slight decrease in summer rainfall; also, winter rainfall has been more variable than summer rainfall, with more than 400mm difference between the driest winter and the wettest winter since 1990. Thirdly, there were notable rainfall episodes that were significantly at variance with UKCP's 1961-90 average, including:

Winter 1975-76 & summer 1976:	62% and 64% drier respectively
Winter 1989-90:	98% wetter
Winter 1993-94 & 1994-95:	75% and 80% wetter respectively
Summer 1995:	78% drier
Autumn 2000:	84% wetter
Summer 2007:	60% wetter

2.9. Concerted adaptation was important for water utilities in certain cases, particularly where dry periods stretched to 18 months or more (as was the case in 1975-76) or where intense or prolonged rainfall had notable local impacts (as was the case during autumn 2000 to winter 2000-01). How often such adaptation measures will be required in future remains to be seen: on the one hand, our overall asset management and understanding of risk has improved; on the other hand, the *average* dryness of summers and wetness of winters will be accentuated, (as summarised in 2.3 above and figure 5 below) and the major storm events are predicted to become more frequent.

Figure 5. Projections applied to average rainfall



Other evidence

2.10. A 2003 study for Defra predicted that under medium high emissions scenarios, climate change would lead to a 1.2% increase in domestic water demand in south-west England by 2025. Using information from the study, we applied lower and upper increases in demand of 1.0% and 1.4% for our headroom assessment, which was included in the supply demand balance calculations for our draft and final water resources management plans.

2.11. In 2008, the Environment Agency reported potential changes to river flows by the 2050s. Under the UKCP 2002 medium-high emissions scenario, total annual flows are projected to drop by 10%-15%. The greatest reductions in flow are projected for September and October: sections of the Bristol Avon and the Tone could fall by 50%-80% and catchments in south Wiltshire and Dorset by 30%-50%.

2.12. Environment Agency flood zone maps show areas that are susceptible to flooding from rivers and the sea. River flood zone maps indicate the extent of a flood with a 1 per cent (1 in 100) chance of happening in any year. Sea flood zone maps indicate the extent of a flood with a 0.5 per cent (1 in 200) chance of happening in any year. The maps also indicate the extent of an extreme flood from rivers or the sea with a 0.1 per cent (1 in 1000) chance of happening in any year. The maps purposefully ignore the presence of existing flood defences, which can be overtopped by floods that are larger than what the defences are designed to withstand.

2.13. In 2007, the South West Regional Assembly produced a Regional Flood Risk Appraisal (appendix 2), as required by Government guidance PPS25. By identifying the source and significance of all types of flood risk across the region, it aimed to influence housing and employment, identify where flood risk management measures may be functional and direct development away from areas at highest risk of flooding. In Wessex Water's region, the assessment identified the Somerset Levels and Moors, Avonmouth, Weston-super-Mare, Bridgwater, Taunton, Weymouth and Christchurch, Bournemouth & Poole as suffering from regionally significant flood risk.

2.14. The South West Climate Partnership produced in 2003 a scoping study for the region of potential climate change impacts entitled *Warming to the Idea*. This has recently been updated to take UKCP09 projections into account.

2.15. A report published in 2010 by Met Office for Ofwat provides projections of changes in the frequency of extreme rainfall events for selected towns and cities. These are based on UKCP09 outputs, using the medium emissions scenario. Examples for our region of projections (taking the central case for probability) showing the increasing frequency of such events are shown below:

Table 4. Changing occurrence of major storms

	Storms of the intensity currently expected to occur…	Would occur by the 2040s…	Would occur by the 2080s…
Bristol winter storms	Once every 10 years	Once every 6 years	Once every 5 years
	Once every 30 years	Once every 17 years	Once every 13 years
	Once every 100 years	Once every 50 years	Once every 35 years
Bristol summer storms	Once every 10 years	Once every 9 years	Once every 8 years
	Once every 30 years	Once every 27 years	Once every 26 years
	Once every 100 years	Once every 92 years	Once every 85 years
Bournemouth winter storms	Once every 10 years	Once every 7 years	Once every 5 years
	Once every 30 years	Once every 17 years	Once every 12 years
	Once every 100 years	Once every 50 years	Once every 35 years
Bournemouth summer storms	Once every 10 years	Once every 8 years	Once every 7 years
	Once every 30 years	Once every 25 years	Once every 20 years
	Once every 100 years	Once every 75 years	Once every 60 years

Uncertainties and thresholds

2.16. Climate change projections are inherently bounded by uncertainty. While there seems to be a clear enough general narrative of warmer, drier summers and milder, wetter winters, we can not know with much precision how these changes will play out in any given year or season. The pace of change over the 21st century is also uncertain. For our part, we are not able to narrow down our own projections using modelling; rather our work is based directly or indirectly on UKCP outputs. We are also cautious about claiming direct links between climate change and individual phenomena where a number of factors are in play. An example is surface water runoff, which is influenced by the increasing coverage in urban areas by impermeable surfaces, as well as changing rainfall patterns.

2.17. So, in general we defer to UKCP on the subject of uncertainty. However, there are potential impacts of climate change that are of particular interest to the water sector that are currently unclear, having not yet been investigated through the UK Climate Projections programme. These include changes to the length of droughts and the return frequency of multi-season droughts in particular. Looking more globally, we will continue to review the assessment reports of the Intergovernmental Panel on Climate Change which express certainty and uncertainty in percentage terms.

2.18. So far, we have not identified specific climate change thresholds above which particular impacts move up from one level of risk to another. For example, we are not in the position to state the temperature increase that would be needed to increase the intensity of storms above the level that could be handled by key sewers or pumping stations. However, we do use certain weather events - such as the 1975-76 drought and 1 in 30 year storms - as reference points or benchmarks for action or investment. Part of the climate change research projects currently funded through UK Water Industry Research (UKWIR) is an aim to understand thresholds and sensitivities better for the water sector (appendix 3).

Summary of short and long term climate change effects

2.19. Taking all this evidence together, table 5 gives an overview of how climate change might affect us in the short to medium term (up to and including the 2020s) and the long terms (the 2030s onwards). As a caveat, it should be noted that in the short term it is difficult to disentangle climate change effects from other factors (environmental and socio-economic alike) while in the long term, uncertainties around the scale and pace of change are greater. Also, we have already experienced most of the envisaged impacts in some shape or form. What we need to plan for is the increasing intensity, frequency and geographic spread of extreme weather events as well as the potential appearance of some entirely new issues.

Table 5. Summary of short and long term impacts in our region

Short term (to end of 2020s)	Long term (2030s onwards)
• 0 – 10% less average summer precipitation • 0 – 10% more average winter precipitation • Intense flooding events at any time	• Up to 30% less summer rainfall (central case) • Up to 20% more winter rainfall (central case) • Reduction in the return period of the most intense storm events • Sea level rise plus 1 in 50y storm events: +1m along south coast, + 1.5m along Bristol Channel, +2m along Severn Estuary

2.20. Also, it is worth noting that we aim to distinguish between weather and climate, which are different, but related. 'Climate' is the average weather experienced by an area, plotted over the long term. 'Weather' describes current conditions and reflects the day-to-day, season-to-season variability that any area experiences, regardless of the norm or the average. Our adaptation plan and this report outline how we need to be able to accommodate any weather, in the context of underlying changes to our climate.

3. Work undertaken to applying evidence of potential climate change in planning and risk assessment

Overview

3.1. Wessex Water has an all-encompassing framework for risk management. The high level 'Turnbull' risks have been overseen by the Board for several years. Our 2010-15 business plan is heavily influenced by assessments of risk to services provided by our assets and direct risks to the assets themselves such as flooding.

3.2. Climate change is an explicit part of our strategic risk register. While the business continuity impacts of individual weather events are already accounted for, the company's Risk Committee and Risk Group keep emergent risks under review, including those associated with climate change.

3.3. For Wessex Water, resilience to the risks posed by climate change is multi-dimensional. It includes our ability to plan ahead; the ability to implement the necessary measures to increase resilience; the physical capacity of our assets; the quality of our emergency response; and our continued provision of excellent service as average conditions change and extreme weather events become more frequent. Our resilience to climate change is partly a question of whether we can cope with extremes: prolonged hot and dry weather that elevates peak demand; intense storm events that overwhelm drainage and the land on which rain falls. Clearly, adaptation measures will be of critical importance in future during periods of extreme variability, when the *average* dryness of summers and wetness of winters has been accentuated. However, most of the possible impacts have happened before at some scale and we have a lot of experience dealing with acute weather-related impacts on operations and as noted earlier, these are built into our planning activities and company risk assessments. The 1975-76 drought was the last time in which hosepipe bans were imposed in the Wessex Water region and is the benchmark for our water resources planning. Summer 1995 accelerated work to reduce leakage across the country. The prolonged rainfall of summer 2007 required widespread emergency response and then led to a fundamental review of surface water management in the UK. Overall, we aim to accommodate in our sewerage system the flows that arise from a 1 in 30 year storm events. The degree to which the ground is already wet or dry influences the amount of runoff and flooding that occurs.

Using existing evidence of weather and climate change-related risk to assess current and future vulnerability

3.4. Our **water resource planning** is designed to test our resources against dry weather over an 18 month period rather than a single dry season. The 1975-76 drought, which we use as our main benchmark, involved a relatively dry summer in 1975, followed by a very dry winter, followed by a relatively dry summer. Since that time, no dry winter and dry summer sequence has been severe enough on its own to cause significant problems, such that we have not had to impose a hosepipe ban since 1976, although this has also been helped by our work to reduce leakage.

3.5. In 2006, an UKWIR project used UKCIP02 outputs to derive 'UKWIR06 scenarios'; these provided a methodology for the water industry to assess specifically the potential impact of climate change on water resource availability. In accordance with Environment Agency guidance for water resource planning we then used the UKWIR06 dry, mid and wet scenarios to forecast each individual source yield up to 2035. The mid forecast indicated a small overall reduction in available supplies of 2.5 Ml/d by 2025 and this was included in our baseline supply demand balance calculations. The dry and wet scenario forecasts enabled us to account for potential variability around the central forecast and these were included in our headroom modelling for our water resources management plan. Our draft water resources management plan (2008) was subject to regulator, stakeholder and public consultation and was also a key element of the business plan we submitted for Ofwat's 2009 Price Review (PR09).

3.6. In conjunction with our AMP4 low river flow investigations for the Hampshire Avon, a groundwater model was jointly developed for the catchment between the Environment Agency and Wessex Water. Modelled natural river flows for the period 1970 to 2006 were compared to modelled natural flows for the same period, that were generated using rainfall and potential evapotranspiration data for the catchment from the UKWIR06 mid scenario. This analysis found that flows at the lower end of the catchment (Knapps Mill) would be 3.5% greater over the whole period under climate change conditions. The analysis also identified some seasonal variations - with typical winter flows (Q10) being approximately 7% higher and typical late summer flows (Q90) being approximately 2.5% lower.

3.7. Following the publication of the UKCP09 projections UKWIR commissioned HR Wallingford to undertake a 'quick-look' project to assess the probability distributions associated with the new climate scenarios and their possible impact on water resources. Using the flow factor approach provided by the methodology we assessed a sample of sources under the new projections. Initial findings indicated that the central forecast (based on the 50th percentile) was broadly similar to the mid scenario of the UKWIR06 assessment. This strengthened our confidence in the UKWIR06 method which formed an integral element to the water resources management plan we were at that stage in the process of finalising. The variability around the central estimate however appeared greater, although it is likely that comparing the UKWIR06 dry and wet scenarios with the UKCP09 5th and 95th percentiles was not strictly appropriate. Given the timing of the publication of the UKCP09 projections it was not possible to model fully the scenarios in the development of our most recent water resources management plan and business plan. This was in line with guidance from the Environment Agency.

3.8. Wessex Water is currently involved in collaborative research with other water companies, the Environment Agency and Defra to enable the water industry to make full use of the UKCP09 scenarios in our next water resources management plan and business plan for the 2014 price review. An UKWIR coordinated project is tasked with developing new methodologies to assess the impacts of climate change of resources availability.

3.9. In 2007-08 we carried out a detailed assessment of the **risk to our operational assets from flooding.** This work complied with the Service Risk Framework for Flood Hazards produced in 2008 Halcrow for Ofwat, for general use in the water industry. This is the main aspect of our climate change work that has been able to assess specific risks for particular locations.

3.10. Screening of water supply assets began by identifying sites located in or adjacent to flood zones as defined by the Environment Agency's flood maps. This was followed by site assessments, modelling of hydraulics of local water course and risk assessment, allowing a long-list of 24 sites to be narrowed down to two that we deemed to be at genuine risk of flooding. Action was found to be cost-beneficial and Ofwat supported investment in its PR09 final determination.

3.11. A similar process was followed to assess flood risks for **sewerage assets and sewage treatment works,** with on-site assessments following interrogation of Environment Agency Flood Maps and our own records of flood events. We proposed mitigation work at nine sewage treatment works and two sewage pumping stations in the PR09 final business plan; in its final determination, Ofwat agreed to support investment at one of these sites.

3.12. The sewerage network is required to cope with high volumes associated with prolonged or intense rainfall. Major investment has been made in the past to prevent flooding of properties from sewage and to reduce the impact of overflows from combined sewers into watercourses.

3.13. Like other companies in our sector, we have not used UK climate projections for planning sewerage services to the same degree as in water resources planning. Nevertheless, we have taken on board the UKWIR 2006 work described above as well as Defra's general guidance of 20% increase in rainfall intensities, as described in appendix 4c. We project that sewer flooding protection against a 1 in 30 year rainfall event will, by 2080 only protect against a 1 in 20 year rainfall event. Ultimately, these projections could not be translated into firm investment proposals in our PR09 final business plan as we had been instructed by Ofwat to wait for revised UKCP projections, that were originally to be released in 2008. Their final release in 2009 was too late for PR09 business plans and Ofwat was reluctant for investment proposals to be based on the earlier UKCIP02 projections.

3.14. Since the business plan submitted in 2009, we have investigated the impact of climate change in Bristol. A 10% increase in rainfall will result in a 20% increase in flooding. This analysis will feed into a sustainable drainage study being carried out by Ofwat in 2011. This will calculate the impact of climate change over the next 30 years and establish the increased risk of internal flooding; we hope that this will inform the Government's policy on surface water drainage, which we expect to see clarified in the forthcoming White Paper.

High level risk assessments

3.15. In 2007-08, Montgomery Watson Harza (MWH) produced a framework for identifying climate impacts, associated risks and potential adaptation responses on behalf of Water UK (appendix 4). It considered temperature, drought, flooding and sea-level rise impacts for the full range of asset types. MWH assigned an 'impact score' for each impact based on urgency (whether the impact was expected in the short-term (pre-2015) or long-term (post 2015)) and severity (whether the impacts would affect life & health or property / other). Our first use of this report was to compare MWH's proposed adaptation measures with our own activity. Then in 2009, we used the impacts identified by MWH as the basis for a public domain overview of climate change risks and adaptation options (see references).

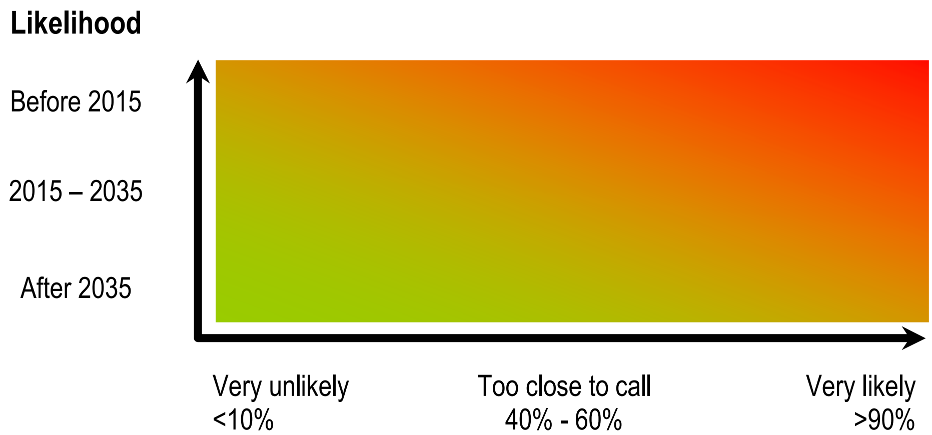
3.16. In 2010 URS published a report for Defra on climate change adaptation: *Adapting Energy, Transport and Water Infrastructure to the Long-term Impacts of Climate Change*. A vulnerability assessment was carried out using the same asset categories as in the MWH / Water UK study (with the identified impacts also closely resembling MWH's work). Impacts were scored according to impacts on the functionality of infrastructure and the likely geographic scale of impacts. Precipitation impacts are considered to be highest (compared with temperature storm and wind impacts), with gradual and sudden impacts on water infrastructure expected throughout the 21st century. The 'key technical risks' were found to be:

- Reduced security of supply due to changing precipitation patterns & drought periods
- Increased fluvial flooding of water supply and wastewater assets
- Increased pluvial flooding of sewerage
- Increased pollution incidents due to changing precipitation patters & drought periods.

3.17. The Government's UK climate change risk assessment, being led by HR Wallingford, is underway and due to report in 2012. Its overall aim is to "*undertake an assessment of the risks (including opportunities) from climate change to those things that have social, environmental and economic value in the UK, to help the Government create an enabling environment for the UK to adapt and identify priorities for action*." We will be taking particular interest in the work on the water and waste water sector assessment, to which Wessex Water and the other companies in our sector have contributed. In the interim, we note the section on flood management, water and waste of the 2010 National Infrastructure Plan. It points to investment in new and existing water and sewerage assets; the need to encourage water efficiency; and that flood risks should be addressed through long term planning, pooling of resources, raising public awareness and development control.

3.18. Wessex Water's own risk appraisal for our adaptation plan considered the likelihood and consequence of the different potential climate change impacts identified by MWH, using a scoring system explained in appendix 5. Likelihood is scored from 1-5, based on the probability of impacts occurring over different timescales; the consequence score (also from 1-5) considers the geographic scale of impact and the things that would be affected.

Figure 6. Likelihood and consequence matrices for risk assessment



3.19. The company's asset managers were involved in two scoring exercises - one for water supply and one for sewerage, sewage treatment and sludge. We also referred to the outputs of UKCP2009 in a relatively pragmatic way, focusing on central case projections of winter and summer rainfall for the 2020s and 2050s (appendix 1).

3.20. We acknowledge that this approach is neither completely objective nor lacking uncertainty. Subjective judgements are brought to bear, but we are confident that our assessments are based on good quality information that we have gathered and the accumulated local knowledge of company staff. The MWH inventory is also heavily focused on physical assets employed for providing water and sewerage services. Future risk assessment may need to incorporate other issues, such as the impacts of heatwaves on the health and safety of employees; the resilience of our supply chain during flooding events; and any adverse effects on our estates beyond our operational sites.

4. Identified levels of risk

4.1. This section outlines the results of past risk assessments and the specific risk assessment exercise carried out for our adaptation plan.

Main findings of high-level risk assessment

4.2. The scores given for each of the potential impacts identified by MWH are provided in appendix 4; those with a score of 12 or more, which can be thought of as our higher priority climate-related risks, are shown in tables 6 and 7 that follow.

4.3. Regarding the main potential impacts, changes to precipitation dominate the risk assessments that we have carried out; this is corroborated by external work such as the URS study of impacts on energy, water and transport infrastructure. Temperature increase is a lesser concern in terms of the performance of our operational assets, but could affect peak demand and cause odour problems at wastewater assets. Sea level increase is less evident in our risk hierarchy in the short to medium term. However, for certain areas it could become more important in the long term in combination with coastal storms.

4.4. In terms of the **quantity of water available for public supply**, the risk assessment reflects previous exercises as described in 3.4-3.13 above. As noted, it is difficult to disentangle the effects of climate change from other factors; nonetheless, for the 25 year planning horizon at least, the medium emissions scenario suggests only small reductions in yield. UKCP09 also suggest that changes to summer and winter rainfall in an *average* year will balance each other to the 2050s. Either way, assessments of the impact of climate change on water resource availability suggests that under the medium emissions scenario (as used for baseline forecasting) impacts are small and so do not represent ‘high priority risks’. Climate change on its own does not appear to pose a high risk for water resource quantity over that time period.

4.5. **Water resource quality** is more likely to be compromised by climate change in the medium to long term than water quantity. Warmer summers are likely to bring reductions in quality due to biological activity that is triggered by warm weather. Heavy rainfall – both in prolonged episodes or short, sharp spells – can result in contaminants being washed into reservoirs or supply pipes.

4.6. Regarding **wastewater services**, the highest risks relate to flooding from combined sewers during intense or prolonged rainfall, with adverse impacts on customers and receiving watercourses. Other high risks include odour during warm weather; reduced dilution in receiving waters during drought; and sedimentation in sewers, also due to drought.

4.7. There may be some specific benefits from climate change. For example, milder winters would help some sewage treatment processes; warmer conditions could reduce heating costs and increased winter rainfall would mean earlier recharge and reservoir filling.

Table 6. Findings of risk assessment – water supply

Change / hazard	Effects on assets & services	L	C	R	Code
Higher temperatures	Poorer quality raw water e.g. discolouration and odour caused by growth of algae and other micro-organisms promoted by warmer conditions.	5	4	20	T10, T12, T15
	Increasing water demand, reducing security of supply	3	4	12	T2, T3
	More extreme wetting-drying cycles, leading to soil movement & pipe bursts	3	4	12	T20
Drought	Lower dilution (of contaminants), with risk to drinking water quality	3	4	12	D11
	Lower yields from some sources, increasing demand on other sources / existing storage	3	4	12	D6, D9
More intense / prolonged rainfall	Poorer quality raw & drinking water, due to sedimentation, turbidity	4	4	16	F13, F14
	Direct flooding of water supply assets, leading to service failure	3	4	12	F1,F4, F11, F17
	Loss of power supplies, requiring back-ups to avoid service failure	3	4	12	F2, F12, F17

Table 7. Findings of risk assessment – sewerage

Change / hazard	Effects on assets & services	L	C	R	Code
Higher temperatures	Increased odour from sewage treatment works and sludge	4	4	16	T38, T53
	Greater septicity, affecting the performance of sewage treatment	4	3	12	T45
	Effluent standards tightened due to warmer receiving waters	3	4	12	T39
Drought	Lower river flows leading to increased risk of tightening discharge standards over time	4	4	16	D36
	Lower flows to sewage works, leading to longer retention in settlement tanks and odour problems	4	4	16	D34
	Sedimentation in sewerage causing blockages, leading to sewer flooding, spills from combined sewers and pressure on treatment works	4	4	16	D24, D27, D31
More intense / prolonged rainfall	Flooding of properties as combined sewers and surface water sewers are overwhelmed	5	4	20	F24
	Capacity of pumps and / or combined sewers exceeded, leading to spills that reduce receiving water quality	5	4	20	F23, F27, F30, F32
	Groundwater infiltration into sewers, leading to sewer flooding	5	3	15	F25
	Direct flooding of sewage treatment works / critical pumping stations	3	4	12	F12,F33
	Flooding of transport routes and waterlogging of fields, affecting sludge recycling operations	4	3	12	F45, F46
Sea level rise and coastal storms	Combined sewers at full capacity during high tides, leading to customer flooding and discharges reducing water quality	3	4	12	S14, S18
	Direct loss of assets, particularly if coastal realignment was required	3	4	12	S19

The coding on the right refers to the detailed tables in appendix 4

L – Likelihood; C – Consequence; R – Risk

5. Our adaptation plan

5.1. Before setting out specific actions or work areas currently undertaken or proposed by Wessex Water to adapt to climate change, it is important to explain certain points of context.

5.2. Firstly, we make a distinction between **instructed adaptation** and **complimentary adaptation**. Instructed adaptation includes cost-beneficial actions agreed by Ofwat with an explicit climate change adaptation driver, as part of our agreed AMP programme and can be thought of as 'adaptation by design'. Complimentary adaptation includes other work that will help us withstand greater extremes in future weather patterns as the climate changes, but are not formally recognised by Ofwat in our case as climate change adaptation measures. This could also be described as 'adaptation by default'. It includes work funded as part of the AMP programme – but not as explicit climate change adaptation – and also discretionary investment. Some of this work is very long-standing, having been devised before any risk assessment concerning climate change *per se*. These activities are also determined by the standards of service that we aim to achieve and our goal for stable asset condition.

5.3. Our adaptation plan is informed by our view of risk as set out in section 3. Risks are ranked, and schemes prioritised to reduce high risks to an acceptable level. Typically, the risks are location specific and the timescales for investment depend on funding. Proposed measures for the highest risk impacts are shown in tables 9 and 10, with other measures shown in table 11.

5.4. It would not make sense for us to attempt to adapt to climate change in isolation. A good proportion of our work requires co-operation and in some cases shared responsibility, with other agencies that are also affected by extreme weather. These include energy and telecoms providers, local authorities, transport providers and those maintaining transport routes, the health service and tourist organisations. Further details are provided in 6.7-6.9.

5.5. We do not claim certainty either about the pace of climate change in our region, the consequences for our services or the appropriateness of the adaptation measures in our plan. Instead, uncertainties need to be acknowledged. Changes may be more gradual or more rapid than envisaged; changes may also turn out to be more or less pronounced than projected. We are working on the best current available evidence (the UK Climate Projections) and our current view of the best responses, but adaptation measures will themselves need to adapt and change with time.

5.6. Taking all these points into account, the plan that follows sets out our current preferred approach or direction of travel and the activities that will help us adapt (even if they were not initiated with climate change adaptation as an explicit driver) according to the best available information at present. In a minority of cases, investment has been agreed by our regulators with climate change as a stated driver.

Water supply – instructed adaptation

5.7. Ofwat approved investment at two water supply sites during 2010-15 to reduce flood risk. Work will include enhancement of existing bunding; installation of flap valves and alarms; on-site drainage improvements; flood protection barriers and raising of critical plant. Our supporting analysis for this investment was commended by Ofwat in its 2010 report "Climate change – good practice from the 2009 price review". Ofwat's comments are shown in appendix 6.

Table 8. Higher risk impacts – water supply

Change / hazard	Effects on water supply assets & services	Risk / 25	Instructed measures in 2010-15	Complementary adaptation*
Higher temperatures	Poorer quality raw water e.g. discolouration and odour caused by growth of algae and other micro-organisms promoted by warmer conditions.	20	-	• Water Safety Plans, catchment management • Ongoing monitoring, sources taken offline temporarily if levels are exceeded • Enhanced treatment if needed e.g. Granular Activated Carbon
	Increasing water demand, reducing security of supply	12	-	• Leakage reduction, trials of innovative tariffs, general demand management work, lobbying for metering on change of ownership
	More extreme wetting-drying cycles, leading to soil movement & pipe bursts	12	-	• Reactive repair; mains replacement where justified
Drought	Lower dilution (of contaminants), with risk to drinking water quality	12	-	• Water Safety Plans, catchment management • Ongoing monitoring, sources taken offline temporarily if levels are exceeded • Enhanced treatment if needed e.g. Granular Activated Carbon
	Lower yields from some sources, increasing demand on other sources / existing storage	12	-	• Water resources planning & drought planning • Monitoring of general supply-demand balance and availability at particular locations
More intense / prolonged rainfall	Poorer quality raw & drinking water, due to sedimentation, turbidity & other contaminants	16	-	• Water Safety Plans, catchment management • Ongoing monitoring, sources taken offline temporarily if levels are exceeded • Increased backwashing; enhanced treatment if needed e.g. Granular Activated Carbon • Reservoir dredging
	Direct flooding of water supply assets, leading to service failure	12	Flood protection: two water treatment works	• Ongoing flood risk assessment, review of flooding incidents elsewhere. • Longer term: co-operation with land users upstream, others with interests in flood defence
	Loss of power supplies, requiring back-ups to avoid service failure (all water supply assets)	12	-	• Standby generators; response and recovery plans

* Our Integrated Grid project improves our resilience against each of the three climate change pressures shown here. Ofwat recognises that it improves our resilience in general but does not explicitly mention climate change as a driver for the scheme.

Water supply – complimentary adaptation

5.8. Ofwat agreed funding for Wessex Water to develop a more integrated water supply grid; work will start in 2010/11, to be completed in 2017/18. Although the main drivers for this scheme were abstraction licence reductions, threats to water quality and growth in demand it also builds greater resilience into our supply system. It enables us to mitigate the small yield reduction forecast by UKWIR's middle climate change scenario and provides flexibility in the event of outages in the supply system.

5.9. Some of our other wider water supply activities are complimentary to our climate change adaptation plan as they ensure the reliability of supplies and strengthen the resilience of our supply demand balance. Such activities include:

- Reducing water quality risks from source to tap through our water safety plans; catchment management; process monitoring; taking sources offline temporarily if needed; asset maintenance (such as reservoir desilting).
- Leakage reduction: we have halved leakage since 1995 and it now stands at 74 Ml/d in line with our regulatory targets, 'freeing up' additional water supplies. Consequently, the average daily amount of water we put into the supply system has fallen steadily since the mid-1990s and is now 20% less than in 1995-96.
- Demand management work: our water efficiency strategy actively seeks to help customers use water wisely and avoid waste through a range of education, information and device measures. Our information tries, where appropriate, to raise our customers' awareness of the links between weather, climate, water resource availability and the environment.

Sewerage - instructed adaptation

5.10. The single improvement during 2010-15 agreed by Ofwat for our sewerage service in which climate change adaptation is cited, involves a sewage pumping station in an urban area. The work will involve relocating a motor control cubicle and motors to positions above the flood level. As with the two approved water supply flood resilience projects, the case that we made for this investment was commended by Ofwat in its 2010 report "Climate change – good practice from the 2009 price review". Ofwat's comments are shown in appendix 6.

Sewerage - complimentary adaptation

5.11. Our draft business plan for 2010-15 proposed investment to provide protection against internal sewer flooding of properties in the event of a 1 in 75 year storm; we believe this is a sound long term objective. However, providing this high level of protection was significantly more expensive than the existing 1 in 30 year standard. Given Ofwat's feedback on our draft plan, the delay of UK Climate Projections to 2009 Climate Impacts Programme, the current economic climate and our desire to keep customers' bills stable, we decided in our final business plan to retain our existing 1 in 30 year protection for internal flooding as our minimum design standard. This also aligns with the industry's 'Sewers for Adoption' standard and Defra's proposed unified build code for new sewers. We will keep this under review in the light of emerging climate change predictions. In the meantime, Ofwat agreed a programme of work to alleviate sewer flooding in 2010-15, as summarised in table 9.

Table 9. Agreed sewer flooding and surface water management 2010-15

Internal hydraulic capacity flooding problems to be mitigated	40
External hydraulic capacity problems to be mitigated	60
Internal hydraulic (2 in 10 and 1 in 10) flooding problems to be solved by capital solutions	200
Internal hydraulic 1 in 20 flooding problems to be solved by capital solutions	138
External hydraulic problems to be solved by capital solutions	170
Surface water management plans, assisting local authorities	12

The likely means of achieving these goals over the next five years include increasing sewer capacity (oversizing or duplicating); provision of storage to attenuate flows; provision of sustainable urban drainage solutions; isolation of problems from the system; negotiating new or upgraded overflows; walls or landscaping that divert flows away from properties or areas where the consequences of flooding are great, to areas of lower impact; and sealing sewers where groundwater infiltration has caused problems. Overall, local hazards and corresponding adaptation options will be assessed on the basis of risk and cost benefit analysis.

Table 10. Higher risk impacts – wastewater

Change / hazard	Effects on wastewater assets & services	Risk / 25	Instructed measures in 2010-15	Complementary adaptation
Higher temperatures	Increased odour from sewage treatment works and sludge	16	-	• Local odour control / mitigation
	Greater septicity, affecting the performance of sewage treatment	12	-	• Local odour control / mitigation; increased / additional aeration
	Effluent standards tightened due to warmer receiving waters	12	-	• Investment if required by environmental regulators and supported by Ofwat
Drought	Lower river flows leading to increased risk of tightening discharge standards over time	16	-	• Investment if required by environmental regulators and supported by Ofwat
	Lower flows to sewage works, leading to longer retention in settlement tanks and odour problems	16	-	• Local odour control / mitigation
	Sedimentation in sewerage causing blockages, leading to sewer flooding, spills from combined sewers and pressure on treatment works	16	-	• Sewer maintenance (jetting etc)
More intense / prolonged rainfall	Flooding of properties as combined sewers and surface water sewers are overwhelmed	20	-	• Funded work to alleviate sewer flooding of properties(local solutions) • Surface water management plans - joint implementation • Improvements at individual CSOs • Flow modeling to predict local impacts of rain events, drainage area plans • Sealing sewers experiencing groundwater infiltration
	Capacity of pumps and / or combined sewers exceeded, leading to spills that reduce receiving water quality	20	-	
	Groundwater infiltration into sewers, leading to sewer flooding	15	-	
	Direct flooding of sewage treatment works / critical pumping stations	12	One sewage pumping station: raising controls above flood level	• Ongoing flood risk assessment, review of flooding incidents elsewhere. • Longer term: co-operation with land users upstream, others with interests in flood defence
	Flooding of transport routes and waterlogging of fields, affecting sludge recycling operations	12	-	• Use of portable trackway to access fields; driers to minimise sludge volumes
Sea level rise and coastal storms	Combined sewers at full capacity during high tides, leading to customer flooding and discharges reducing water quality	12	-	• Funded work to alleviate sewer flooding of properties(local solutions) • Surface water management plans with stakeholders in tide-locked catchments
	Direct flooding / loss of assets, particularly if coastal realignment was required	12	-	• Flood risk assessments; investment to protect sites if agreed by Ofwat; relocation of sites / flows where necessary

5.12. We will also carry out investigations during 2010-15. We will be applying the latest predictions for changes to rainfall and their potential impacts and using hydraulic computer models to forecast future scenarios which will be presented in our AMP6 Business Plan. If we obtain funding in AMP6, we will design new schemes to accommodate climate change.

5.13. While we have already applied the principles of sustainable urban drainage systems (SUDS) and integrated urban drainage, Surface Water Management Plans (SWMPs) have been initiated by the Government to improve understanding of flooding risks. These may result in solutions to complex problems being allocated among a range of stakeholders, including local authorities, the Highways Agency, the Environment Agency and riparian owners. This approach is particularly applicable for external sewer flooding problems as approximately 15% of those investigated are multi-agency problems (i.e. not solely attributable to the lack of capacity in our infrastructure) and will require a joint approach to develop a satisfactory solution. Our contribution to SWMPs in our region during 2010-15 will include data sharing; producing GIS plans of drainage systems; sewer capacity assessments; sharing model results; encouraging developers to use sustainable urban drainage systems (whilst ensuring their design incorporates consideration of exceedance flows); identifying and costing separation of some surface water flows; and elimination of sewer misconnections. We will also appraise and promote sustainable solutions such as water butts, rain-water harvesting, permeable pavements, specially designed roofs and underground storage lagoons, as well as managing the flow of surface water through kerb raising and bund construction.

5.14. Looking further ahead, we do not believe that increasing surface water runoff due to climate change can be economically contained in enclosed pipe systems. The 2008 Pitt Review states "*…it is simply not possible to increase the capacity of the whole sewerage system*"; for potential flood alleviation schemes we compared the cost of providing protection against a 1 in 75 year storm event with our standard 1 in 30 year storm event protection and found that the former is significantly more expensive. Instead, tackling surface water at source is clearly the most effective approach. We need to 'make space for water'; this can mean keeping water above ground, in a controlled manner so it has less of an impact rather than simply adding it to constrained drainage systems. It also involves encouraging slow absorption of surface water by using permeable hard surfaces, protecting natural and semi-natural features in flood plains, and retaining water in the upper parts of river catchments. We will also press for changes to the planning systems, notably:

- restrictions on laying impermeable surfaces
- removal of the automatic right to connect surface water drainage to the sewerage system
- clarification by Government of flooding legislation and the ownership of SUDs.

Cost and benefits of proposed measures

5.15. Cost benefit analysis is now integral to the five year business plans that we submit to Ofwat. We must give full account of the costs that we estimate for delivering outputs and clearly explain the benefits that we expect to be gained as a result. If a scheme is not mandatory – for example, if it is not required by an EU directive – there must be good arguments on cost / benefit grounds to secure agreement. The principal benefits for the 'instructed adaptation projects' during 2010-15 are reduction of the risk of disruption from flooding. The benefits of other 'complimentary adaptation' work are in their provision of operational headroom and the fact that they increase our ability to provide expected standards of service in the face of more extreme weather events.

Table 11. Other adaptation measures for low to medium risk impacts

	Forward planning	Investment schemes and ongoing operations	Work with others
ALL ASSET GROUPS	• Flood risk assessments to highlight the most at-risk assets and priorities • Modelling risk & investment using asset deterioration models • Adapting maintenance plans	• Working to response & recovery plans during extreme weather events and coastal flooding • Adapting working practices ref. health and safety e.g. heatwaves, hydrogen sulphide, insect risk	• Responding to regulators' & customers' expectations of improving service levels e.g. reducing interruptions to supply
Water resources & treatment	• Investigating alternative sources or relocating sources if a change in yield is observed or forecast • Altering existing assets to optimise use of resources • Drought planning	• Monitoring processes & water quantity • Reservoir inspections (siltation, slippage, overtopping, dam breaks); desilting reservoirs when needed • Optional metering • Low flow studies	• Consulting on work e.g. low flows studies, our water resources plan, emergency response plans • Catchment management to protect groundwater from nitrates & pesticides • Lobbying for metering on change of ownership
Water networks	• Modelling flows and water quality for better response to supply interruptions &, changing water quality • Water network service plan	• Ongoing leakage reduction and pressure management	• Raising awareness of work to increase the resilience of our supply network
Sewerage	• Modelling catchments to guide sewerage investment • Using LIDAR to map topography and predict areas at risk of flooding • Protection to 1:30 year standard (internal flooding) and 1:20 year standard (external flooding) • Flood alleviation schemes (investigation, implementation if necessary) • Local capacity improvements • Improved rainfall modelling	• Monitoring run-off and flood flows • Work to reduce infiltration of groundwater into sewers • Separation of surface water and foul sewers if cost beneficial • Local investment e.g. sedimentation points, non-return valves • Reviewing and optimising operating and maintenance regimes • Learning from warmer regions ref. managing septicity • Pumped overflows during river flooding	• Co-operation with other agencies in developing and implementing Surface Water Management Plans • Discussing individual and shared responsibilities for sewerage and drainage with local authorities • Discussing with regulators pragmatic solutions to sewer flooding caused by high groundwater levels • Raising awareness of emergency response strategies and potential future levels of service.
Sewage treatment	• Ongoing review of capacity and flow consents at specific works • Ongoing review of treatment options and performance of different processes during extreme weather • Modelling of STW catchments ref. storm storage requirements	• Increasing capacity at sewage works according to changes to incoming flow and population; • Gradually changing operations and maintenance as quantity and quality of sewage received changes e.g. staggering discharges across the day • Gradually increasing wastewater treatment to achieve higher effluent & water quality standards • Monitoring sewage quality, trade effluent regulation • Providing effluent for re-use (selected sites)	• Discussions ref. EU Water Framework Directive and catchment management • Discussing alternative types of effluent discharge consents to accommodate extremes in weather
Sludge	• Considering the possible impacts of flooding on the reuse of sludge on agricultural land • Including resilience in sludge strategy e.g. energy self-sufficiency at key sites	• Gradually altering operating and maintenance regimes to deal with changes to sludge quantity & quality	• Maintaining good relationship with farmers to help retain flexibility in terms of where we can reuse sludge.

5.16. It is rarely the case that we can isolate the effects of climate change *per se* on a given situation and therefore the specific costs and benefits of climate change adaptation. Rather, there are typically a number of individual but interacting factors coming into play. For example, in the development of the water resources management plan it was necessary to look holistically at the full range of issues that influence water supply and demand, such as population growth, changes in households' typical water use and the condition of water supply assets as well as climate change projections. Therefore, the costs and benefits of adaptation to climate change were considered as part of this process, but not specifically on their own and it would be difficult to separate them out.

5.17. The agreed costs of climate change adaptation measures for 2010-15 and beyond are not included in this report for reasons of commercial confidentiality.

Risk reduction

5.18. The risk assessment scores shown in this report are for current levels of risk. In all cases, we aim to reduce risk to an acceptable level, such that we can continue to provide expected levels of service, even if in some acute cases we have to make a focused effort and deploy extra resources to do so. Our work to manage risk will come through both our investment planning and work with external organisations and customers. Mitigation work will typically be focused on reducing the *consequences*: for example, it may be difficult to reduce the likelihood of a site being flooded, but we may be able to change the layout of the site to limit the effects of the flooding. This work will reduce risk at sites where investment has been agreed, typically during the five year timescale of our regulated investment programme. However, it will not always be the case that this leads to the corresponding risk score being reduced significantly for the company as a whole, as there may be sites that remain vulnerable but have not had investment approved by our regulator.

5.19. While we will be open to any feedback on our risk assessments and adaptation plan, we propose to revisit this exercise and following the publication of the next round of UK Climate Projections. This will allow a review of the residual risk where climate change adaptation schemes have been implemented, as well as revisiting our assessment of risks in general. We will also be reviewing the residual risks that are scored highest in the preparation of our business plan for 2015-20.

6. Implementing climate risk management: embedding, monitoring, interdependencies and barriers

6.1. This section outlines current efforts to build understanding of climate change into work, as well as consideration of other organisational issues.

Managing climate change risks within Wessex Water

6.2. The management of climate change risk has been embedded explicitly at a strategic level within our organisation for at least five years; it has also been part of our water resource planning over that period. As explained in section 3 our overall **risk management** framework explicitly names climate change as a strategic risk for the company. The success of our adaptation plan will be tested by our ability to respond and maintain normal service during future extreme weather events.

6.3. Consideration of future changes driven by climate change impacts is particularly evident in the **investment planning** carried out by our Regulation and Assets Department. The investment needed in the medium and long term to meet standards expected by customers and regulators and to accommodate future growth in population and flows, has to reflect the effects of climate change. Thus, as outlined previously, water resources planning and ongoing UKWIR projects (also supported by the Environment Agency) are incorporating UKCP09 projections. This information feeds into the five-yearly review of source yields as part of water resources management planning. We are reviewing design standards for sewerage to take account of future increases in peak flows, using UKCP09 projections. Across the business, we plan for the future and in turn request funding from Ofwat to address any high risk problems that are identified. We look to regulators to review the levels of service given by our sector and to ensure there is no detriment caused by external factors. Table 10 above includes relevant planning activities.

6.4. Ongoing **monitoring** of climate change impacts and the success of our adaptation has a number of aspects. For water supply, we review source yields at least once every five years as part of the business plan and water resources plan processes. Actual data is considered and yield reductions since previous assessment will be monitored, but not all changes in yield can or should be attributed to climate change on timescales of only a few decades: weather variability, hydrometric monitoring improvement and data management may also have an influence. For sewerage and sewage treatment, we are monitored against stable levels of service and asset condition such as the performance of combined sewer overflows; as climate change happens we will need to review the performance of these assets during more extreme rainfall events. Any new flooding will be assessed and the viability of implementing flood alleviation schemes will be investigated. We are currently installing new telemetry at 42 combined sewer overflows to record the duration of spill events. This will help us assess any deterioration in the performance of these assets. However, as for water supply, attribution of cause and effect is not straightforward in the area of sewerage planning. For example, distinguishing between the effects of land use change (such as urban creep) from the effects of weather events and longer term climate change will be challenging.

6.5. Embedding climate change adaptation is also about having access to **knowledge** that informs decision making. We employ several technical specialists and take part in national research programmes and conferences. More frequent guidance and questions from our regulators mean we must stay informed of developments and latest thinking on future impacts.

6.6. Our adaptation plan and management of climate change risk will not be fixed in perpetuity. Although we can set out preferred approaches, it is important that **adaptation is flexible** as new data emerges or risk assessments change. Our planning cycles can help, such as the production of the water resources plan every five years which involves revisiting current climate change projections. Flood risk assessments and associated mitigation work will need to flex, as the impacts of weather events and local floods are reviewed. The degree to which Surface Water Management Plans succeed in dealing with heavy rainfall is also likely to lead to changes to our sewerage investment and our adaptation plan.

Interdependencies

6.7. Close work with **outside interests** is important for our work to succeed. Good communication with climate modellers, regulators, customers (with regard to saving water during drought) and other utility providers is needed. This is very evident for surface water management, where a deliberately multi-agency approach involves liaison with councils, Internal Drainage Boards and the Highways Agency. Interdependency is equally evident in emergency response. Firstly, a protocol has been developed within the water sector for sharing resources and a Mutual Aid Scheme is operated through which companies co-operate during emergencies. Examples of its recent use include the sharing of bottled water and bowsers during the summer 2007 floods and important lessons were learnt about co-operation between water companies. Secondly, in such situations it is also important that there are good working relationships with local authorities, emergency services and business partners such as suppliers and contractors – who may themselves be affected by intense weather events.

6.8. We are heavy users of other utilities, in particular electricity and telecommunications, so the reliability of these services is important to us. The flooding of an 11kv electrical substation adjacent to our Ham sewage works near Taunton during the prolonged autumn rain in 2000, highlighted the risk for us. The issue was of course underlined hard with the 2007 floods which affected electricity and water supplies in one of our neighbouring regions. We are aware of work carried out by Western Power Distribution with its industry partners, regulators and Government on sector-wide guidance for flood and other climate risks, in order to identify risks and develop solutions for assets, including major electricity substations, of 33kV and above serving many thousands of customers. The electricity sector, and its regulator Ofgem have initiated actions to mitigate flood risk at the major s/s, but as the lower voltage 11kV s/s are normally co-located with the demand they serve, if they were to be flooded so, in general, would be the customer served. Given that there are some 600,000 11kV s/s in UK, the industry approach is to replace flooded units, rather than seek to mitigate at huge societal expense, on the basis that can be done faster than the flooded customer would be ready to re-occupy. We look forward to reviewing details when the electricity sector and other utilities produce their own reports under the adaptation reporting power in due course. We have some contingency measures in place, such as our own standby power generation which can be deployed at short notice. This includes both permanent generators as key locations and smaller generators which can be moved from one location to another.

6.9. Good communication with customers – both domestic and commercial – will be critical for successful climate change adaptation. Customers' needs and expectations will always be a critical concern and we will need to keep track of how these evolve over time. We will be expected to provide excellent service regardless of weather conditions and also to make allowance for climate change in our planning. It will be important to communicate our options and possible approaches in effective ways, although it is a complex set of issues being conveyed. We will also need the goodwill of our customers and the help of the media to both help us cope with acute, extreme weather events and to make longer term, more gradual adaptations to climate change.

6.10. Co-operative working relationships with government and our regulators are essential for our day-to-day activities and longer term planning alike. This is equally true for climate change. We will need to explain our understanding of likely impacts in our region and produce well-reasoned cases for investment where we believe it is necessary.

Barriers

6.11. The main **barriers to climate change adaptation** are financial, regulatory and technical. Examples include:

- the upfront cost of capital-intensive engineered measures and their affordability to those who pay; this can be problematic if costs are to be recovered from customers, or if the economy is fragile and there are many other competing calls on investment
- the timing of the publication of climate projections: this does not necessarily synchronise well with when major decisions are being made on investment, presenting problems for the water companies at the 2009 Price Review
- uncertainty and the limits of existing knowledge, e.g. concerning the pace and scale of climate change and its impacts; the intensity of certain types of weather event at different future time periods; or which locations will be affected the most
- delays due to complexity, particularly if many agencies with varied funding arrangements and cycles are involved in implementing the potential solutions
- potential unintended consequences of adaptation measures e.g. moving flooding from one location to another rather than absorbing storm water; or having a high embedded carbon footprint.

These factors, individually or in combination, can mean that decision makers and funding organisations are very cautious about giving the green light to investment underpinned by climate change adaptation goals. Currently, there is no firm regulatory framework for climate change adaptation; instead, government departments and related agencies are focused on the provision of advice, developing technical knowledge, and mandating certain organisations to report on their adaptation work. At the time of this report's production, it is not surprising that regulators and Government are cautious about, given the uncertainty about the best approaches to adaptation and the relatively short supply of funding for public goods.

6.12. To address these barriers we will need better projections, more sophisticated risk appraisal, and continued monitoring of the locations or aspects of our service which are most vulnerable. This in turn should help prioritise the use of limited funding. There will also need to be better sharing of information among interdependent organisations – a process which we are beginning to see in the development of Surface Water Management Plans.

6.13. These points are reflected in PricewaterhouseCoopers 2010 report "*Adapting to climate change in the infrastructure sectors*", as part of a study commissioned by Defra. It focuses on "*whether market, policy and regulatory models in the infrastructure sectors, together with Government policy and legislation more generally, provide adequate incentives (both positive and negative) to infrastructure providers to consider climate resilience across their existing economic infrastructure and future investment in these sectors*." It finds that the main challenge for the water sector is a lack of consensus in how to apply knowledge of climate risks for planning and regulatory purposes. It notes that some adaptation deals with impacts that might not actually occur within a 25 year planning horizon and that it can be difficult to identify the willingness, or obtain the consent, of customers to pay now for future resilience. The report calls for more collaboration within the sector and with Ofwat and other stakeholders to identify potential costs savings, the best ways to build adaptation into regulatory decision making, and tools for risk assessment and dealing with uncertainty.

7. Conclusions

7.1. Several years ago, we acknowledged that climate change is a major long term challenge for the services we provide. Since then, we have been refining our understanding and developing our approach. Our corporate commitment to adaptation was followed by a sector-wide inventory of potential risks and later by our first public document outlining the issues we face and the types of responses we expect to make. Over the last few years, a number of advances have been made. We have integrated the latest thinking from UKCP into our water resources management and assessed the implications for our sewerage network capacity. We have made the case for weather-related resilience measures via our regulated business plan. We have carried out a wide ranging risk assessment to identify the highest risks associated with climate change, with a corresponding adaptation plan approved by our Board and detailed in this report.

7.2. This report is the latest step in a process that will continue for the foreseeable future. While the requirement to report has not brought about a *material* change in how we manage climate risks, it will contribute to the various ways in which we communicate – both internally and externally - the climate change risks we face and the measures we propose in our adaptation plan. This report is by no means our final word on the climate change risks that we face or the adaptation measures that we will adopt. Our approach is not fixed in stone, but will develop as new information emerges and as Government's and regulators' views evolve.

7.3. Having already shared a preliminary draft of this report with Climate South West and Ofwat, we look forward to feedback from others.

PART C SUPPORTING INFORMATION

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Appendix 1. Key outputs from UKCP2009 a) winter rainfall

CENTRE OF WW REGION	2020s			2050s			2080s		
	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	0 to -10%	0 to -10%	0 to -10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%
33%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	+10% to +20%	+10% to +20%	+10% to +20%	+10% to +20%
50% (central case)	**0% to +10%**	**0% to +10%**	**0% to +10%**	**+10% to +20%**	**+10% to +20%**	**+10% to +20%**	**+10% to +20%**	**+10% to +20%**	**+20% to +30%**
66%	0% to +10%	0% to +10%	0% to +10%	+10% to +20%	+10% to +20%	+20% to +30%	+20% to +30%	+20% to +30%	+30% to +40%
90%	+10% to +20%	+10% to +20%	+10% to +20%	+20% to +30%	+20% to +30%	+30% to +40%	+30% to +40%	+40% to +50%	+50% to +60%

WETTEST IN WW REGION	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	0 to -10%	0 to -10%	0 to -10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%
33%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	+10% to +20%	+10% to +20%	+10% to +20%	+10% to +20%	+20% to +30%
50% (central case)	**0% to +10%**	**0% to +10%**	**0% to +10%**	**+10% to +20%**	**+10% to +20%**	**+10% to +20%**	**+10% to +20%**	**+20% to +30%**	**+20% to +30%**
66%	+10% to +20%	+10% to +20%	+10% to +20%	+10% to +20%	+20% to +30%	+20% to +30%	+20% to +30%	+30% to +40%	+30% to +40%
90%	+20% to +30%	+20% to +30%	+20% to +30%	+30% to +40%	+40% to +50%	+40% to +50%	+40% to +50%	+60% to +70%	+60% to +70%

LEAST WET IN WW REGION	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	0 to -10%	0 to -10%	0 to -10%	0% to -10%	0% to -10%	0% to -10%	0% to -10%	0% to -10%	0% to -10%
33%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%
50% (central case)	**0% to +10%**	**0% to +10%**	**0% to +10%**	**0% to +10%**	**0% to +10%**	**+10% to +20%**	**0% to +10%**	**+10% to +20%**	**+10% to +20%**
66%	0% to +10%	0% to +10%	0% to +10%	+10% to +20%	+10% to +20%	+10% to +20%	+10% to +20%	+10% to +20%	+20% to +30%
90%	+10% to +20%	+10% to +20%	+10% to +20%	+10% to +20%	+20% to +30%	+20% to +30%	+20% to +30%	+20% to +30%	+30% to +40%

Probability scoring

10%	(very unlikely to be less than)
33%	(unlikely to be less than)
50%	(central case)
66%	(unlikely to be greater than)
90%	(very unlikely to be greater than)

Appendix 1. Key outputs from UKCP2009 b) summer rainfall

	2020s			2050s			2080s		
CENTRE OF WW REGION	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	-20% to -30%	-20% to -30%	-20% to -30%	-30% to -40%	-40% to -50%	-40% to -50%	-40% to -50%	-40% to -50%	-50% to -60%
33%	-10% to -20%	-10% to -20%	-10% to -20%	-20% to -30%	-20% to -30%	-20% to -30%	-20% to -30%	-30% to -40%	-40% to -50%
50% (central case)	**0% to -10%**	**0% to -10%**	**0% to -10%**	**-10% to -20%**	**-10% to -20%**	**-20% to -30%**	**-10% to -20%**	**-20% to -30%**	**-30% to -40%**
66%	0% to -10%	0% to -10%	0% to +10%	0% to -10%	-10% to -20%	-10% to -20%	0% to -10%	-10% to -20%	-10% to -20%
90%	+10% to +20%	+10% to +20%	+10% to +20%	+10% to +20%	0% to +10%	0% to +10%	+10% to +20%	0% to +10%	0% to +10%

DRIEST IN WW REGION	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	-30% to -40%	-30% to -40%	-30% to -40%	-40% to -50%	-50% to -60%	-50% to -60%	-50% to -60%	-60% to -70%	-60% to -70%
33%	-20% to -30%	-20% to -30%	-20% to -30%	-30% to -40%	-30% to -40%	-30% to -40%	-30% to -40%	-40% to -50%	-50% to -60%
50% (central case)	**-10% to -20%**	**-10% to -20%**	**-10% to -20%**	**-20% to -30%**	**-30% to -40%**	**-30% to -40%**	**-20% to -30%**	**-30% to -40%**	**-40% to -50%**
66%	0% to -10%	0% to -10%	0% to -10%	-10% to -20%	-20% to -30%	-20% to -30%	0% to -10%	-20% to -30%	-30% to -40%
90%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to -10%	0% to -10%	+10% to +20%	0% to -10%	0% to -10%

LEAST DRY IN WW REGION	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	-20% to -30%	-20% to -30%	-20% to -30%	-30% to -40%	-40% to -50%	-40% to -50%	-30% to -40%	-40% to -50%	-50% to -60%
33%	-10% to -20%	-10% to -20%	-10% to -20%	-20% to -30%	-20% to -30%	-20% to -30%	-20% to -30%	-30% to -40%	-30% to -40%
50% (central case)	**0% to -10%**	**0% to -10%**	**0% to -10%**	**-10% to -20%**	**-10% to -20%**	**-10% to -20%**	**-10% to -20%**	**-20% to -30%**	**-20% to -30%**
66%	0% to -10%	0% to -10%	0% to +10%	0% to -10%	-10% to -20%	-10% to -20%	0% to -10%	-10% to -20%	-10% to -20%
90%	+10% to +20%	+10% to +20%	+10% to +20%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%	0% to +10%

Probability scoring

10%	(very unlikely to be less than)
33%	(unlikely to be less than)
50%	(central case)
66%	(unlikely to be greater than)
90%	(very unlikely to be greater than)

Appendix 1. Key outputs from UKCP2009 c) annual average daily temperature

	2020s			2050s			2080s		
CENTRE OF WW REGION	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	0 to +1	0 to +1	0 to +1	+1 to +2	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3
33%	+1 to +2	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+2 to +3	+3 to +4	+3 to +4
50% (central case)	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+2 to +3	+2 to +3	+3 to +4	+4 to +5
66%	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+3 to +4	+3 to +4	+4 to +5	+5 to +6
90%	+2 to +3	+2 to +3	+2 to +3	+3 to +4	+3 to +4	+4 to +5	+4 to +5	+5 to +6	+6 to +7

WARMEST IN WW REGION	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	0 to +1	1 to +1	0 to +1	+1 to +2	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3
33%	+1 to +2	+1 to +2	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+3 to +4	+3 to +4
50% (central case)	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+2 to +3	+2 to +3	+3 to +4	+4 to +5
66%	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+3 to +4	+3 to +4	+4 to +5	+5 to +6
90%	+2 to +3	+2 to +4	+2 to +3	+3 to +4	+3 to +5	+4 to +5	+4 to +5	+5 to +6	+6 to +7

Probability scoring

10%	(very unlikely to be less than)
33%	(unlikely to be less than)
50%	(central case)
66%	(unlikely to be greater than)
90%	(very unlikely to be greater than)

Appendix 1. Key outputs from UKCP2009 d) summer mean temperature

	2020s			2050s			2080s		
CENTRE OF WW REGION	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	0 to +1	0 to +1	0 to +1	+1 to +2	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3
33%	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+2 to +3	+2 to +3	+3 to +4	+4 to +5
50% (central case)	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+2 to +3	+3 to +4	+4 to +5	+5 to +6
66%	+2 to +3	+2 to +3	+1 to +2	+3 to +4	+3 to +4	+3 to +4	+3 to +4	+4 to +5	+6 to +7
90%	+2 to +3	+2 to +3	+2 to +3	+4 to +5	+4 to +5	+5 to +6	+5 to +6	+5 to +6	+8 to +9

WARMEST IN WW REGION	Emissions scenario			Emissions scenario			Emissions scenario		
Probability	Low	Medium	High	Low	Medium	High	Low	Medium	High
10%	0 to +1	0 to +1	0 to +1	+1 to +2	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3
33%	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+2 to +3	+2 to +3	+3 to +4	+4 to +5
50% (central case)	+1 to +2	+1 to +2	+1 to +2	+2 to +3	+2 to +3	+3 to +4	+3 to +4	+4 to +5	+5 to +6
66%	+2 to +3	+2 to +3	+1 to +2	+3 to +4	+3 to +4	+3 to +4	+3 to +4	+4 to +5	+6 to +7
90%	+2 to +3	+2 to +3	+2 to +3	+4 to +5	+4 to +5	+5 to +6	+5 to +6	+5 to +6	+8 to +9

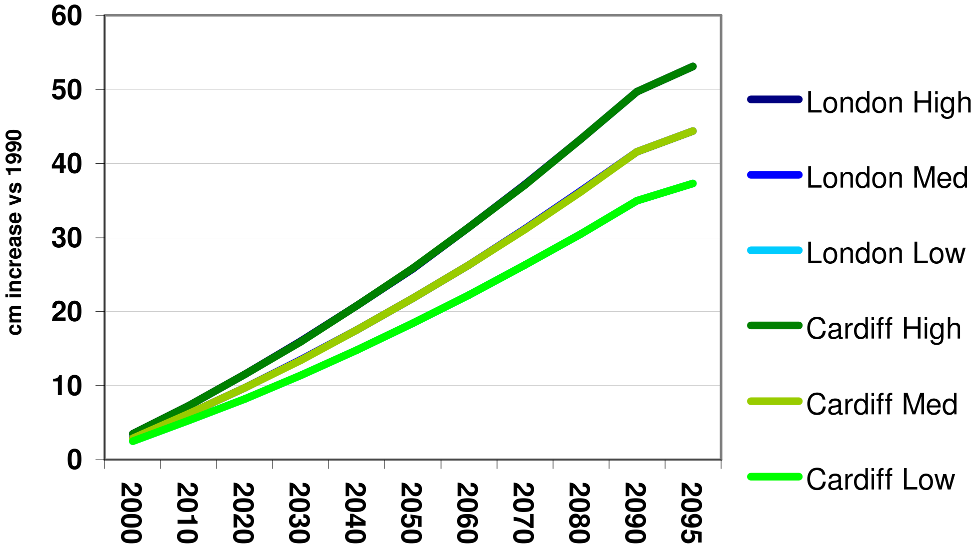
Probability scoring

10%	(very unlikely to be less than)
33%	(unlikely to be less than)
50%	(central case)
66%	(unlikely to be greater than)
90%	(very unlikely to be greater than)

Appendix 1. Key outputs from UKCP2009 e) coastal impacts

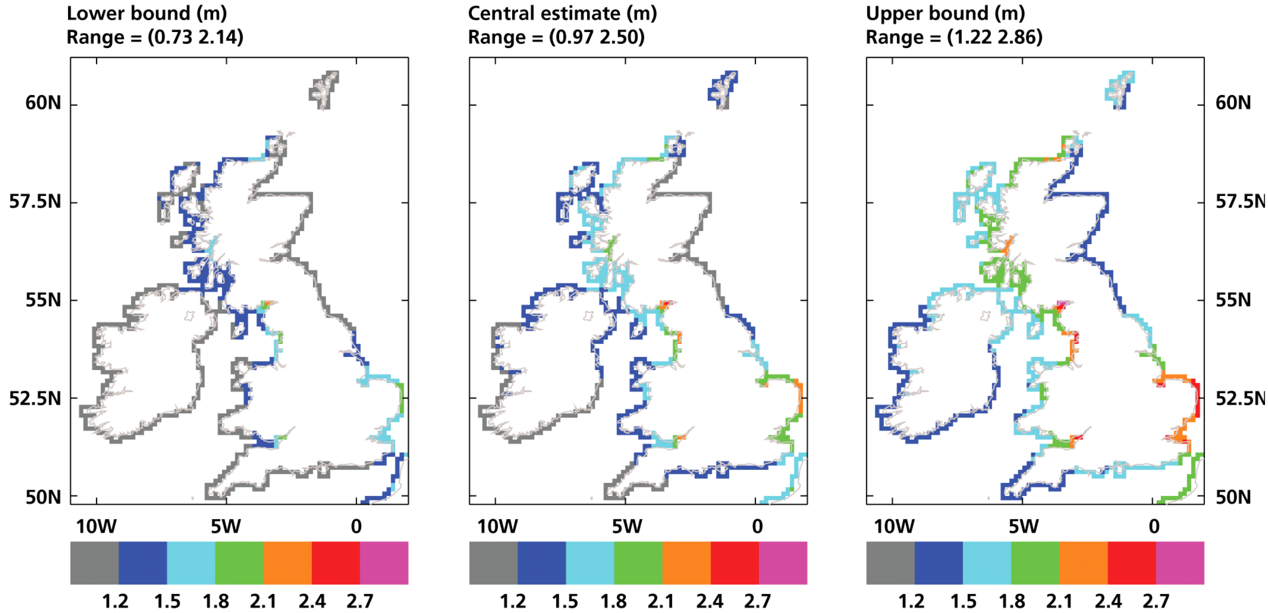
i) Sea level rise (cm increase compared with 1990)

	London			Cardiff		
	High	Med	Low	High	Med	Low
2000	3.5	3.0	2.5	3.5	2.9	2.5
2010	7.3	6.2	5.3	7.3	6.2	5.3
2020	11.5	9.7	8.2	11.5	9.7	8.2
2030	16.0	13.5	11.4	15.9	13.4	11.4
2040	20.8	17.5	14.8	20.8	17.5	14.8
2050	25.8	21.8	18.4	25.9	21.8	18.4
2060	31.4	26.3	22.2	31.4	26.3	22.2
2070	37.2	31.2	26.3	37.1	31.1	26.3
2080	43.3	36.3	30.5	43.3	36.2	30.5
2090	49.7	41.6	35.0	49.7	41.6	35.0
2095	53.1	44.4	37.3	53.1	44.4	37.3



Source: Lowe et al (2009)

ii) Exceedance of present-day astronomical high tides by projected future extreme water 50-yr return levels for 2095 (m).



The central panel shows the estimated central value. Left and right panels show the lower and upper bounds of the 90% confidence interval. Grey shows any value < 1.2 m.

Source: Lowe et al (2009) at http://ukclimateprojections.defra.gov.uk/content/view/1859/500/

Appendix 2. Extracts from South West Regional Flood Risk Appraisal (2007): regionally significant flood risk areas

Weston super Mare & Avonmouth

Weston-super-Mare and Avonmouth are at significant risk from tidal and fluvial flooding and parts of Bristol City are affected by tide locking. Surface water drainage is affected by tide locking.

Tidal defences are planned for Weston-super-Mare, which is expected to protect 4562 properties. Between Avonmouth and Severn Beach there are tidal flood defences that protect up to a 100-year standard. There is currently a feasibility study underway to increase the protection to a 200-year standard. This area is affected by tidal flooding from the Severn Estuary. It is important to remember that even in areas with flood defences there remains a residual risk of flooding in extreme events or as a result of defence failure.

Flood incident management is provided in the form of flood warnings to properties in Bristol, Weston-super-Mare, Severn Beach and Area of Search F to the East of Weston-super-Mare. There are Major Incident Plans containing specific arrangements for warning the public in areas particularly susceptible to flooding in Bath, areas of Bristol, Weston-super-Mare and Uphill.

The effect of climate change and sea level rise is a major concern for Weston-super-Mare, areas of Bristol, Avonmouth and the tidal River Severn. It is estimated that climate change and sea level rise will mean that severe tidal flooding events at Weston-super-Mare and Avonmouth will be six times more likely to occur by 2060 (i.e. a 1 in 200 year event now (0.5%) will become a 1 in 33 year event (3%))

Taunton and Bridgwater & Somerset Levels

Severe tidal flooding events affecting Bridgwater will become significantly more likely with sea level rise. The River Tone presents significant flood risk to the town of Taunton.

In Taunton and Bridgwater there are large areas of development in the fluvial and tidal floodplain and significant numbers of properties are at risk from flooding. In both towns flood peaks and tide locking furthermore affect surface water drainage. The River Tone potentially presents significant flood risk to the town of Taunton although flood protection schemes provide an acceptable standard of protection in most of the lower areas.

In Bridgwater both banks of the River Parrett have large areas with significant flood risks. There are existing fluvial and tidal defences in both these areas and fluvial and tidal schemes are also planned in coming years. Flood defence schemes are planned on the River Parrett and also in Taunton. It is however important to remember that even in areas with flood defences there remains a residual risk of flooding in extreme events or as a result of defence failure.

Flood incident management is provided in the form of flood warnings to properties in the Taunton and Bridgwater areas on the Rivers Tone, Parrett, Halsewater Stream and other areas particularly susceptible to flooding.

The effect of climate change and sea level rise is a concern for significant areas of Bridgwater, particularly between the A38 and M5. It is estimated that climate change and sea level rise will mean that severe tidal flooding events on the River Parrett will be twenty times more likely to occur by 2060 (i.e. a 1 in 200 year event now (0.5%) will become a 1 in 10 year event (10%))

Weymouth

There are flood risks in the town and flood incident management is provided in the form of flood warning to properties. There is flood management infrastructure in the town. There are potential issues relating to the effect of climate change and sea level rise in the town. The SFRA that covers the town explains that flooding is an issue with varying levels of severity across most of the study area, with 13% of properties within the borough located in areas currently at risk of flooding. Significant flooding in the area is mainly caused by overtopping of river banks, whilst less severe flooding generally in Weymouth itself is predominantly from surface water run off and the blockages of drains and culverts.

Bournemouth, Poole and Christchurch
There are significant fluvial and tidal flood risks in Christchurch and Poole. Groundwater flooding is also of concern in this Sub-Region. There are significant fluvial and tidal flood risks in Christchurch and Poole. Groundwater flooding affects Area of Search M, N, O and P and also areas of Poole, Bournemouth, Christchurch, Wimborne Minster, Lytchett Minster and much of the Lower Avon floodplain.

Rivers in the lower reaches are slow to react to rainfall and this can also be exacerbated by tidal events. The effect of the chalk saturation in the upper catchment also affects fluvial flooding in the lower catchment. There are fluvial and tidal flood defences in Christchurch, Poole and tidal defences in Bournemouth. There are tidal and fluvial schemes planned in these areas but it is important to remember that even in areas with flood defences there remains a residual risk of flooding in extreme events or as a result of defence failure.

Flood incident management is provided in the form of fluvial and tidal flood warnings to properties in Christchurch, tidal flood warnings to properties in Poole and also fluvial warnings in Areas of Search O and P. There are Major Incident Plans containing specific arrangements for warning the public in areas particularly susceptible to flooding in Bournemouth and Christchurch.

The effect of climate change and sea level rise is of particular concern in developed and undeveloped areas around Christchurch Harbour and Poole and also in Area of Search M. In addition concerns are being investigated over sea breakthrough at Hengistbury Head. It is estimated that climate change and sea level rise will mean that severe tidal flooding events will be thirty two times more likely to occur by 2060 (i.e. a 1 in 200 year event now (0.5%) will become a 1 in 6 year event (16%)).

Chippenham: there are flood risks in the town and flood incident management is provided in the form of flood warning to properties. There is flood management infrastructure in the town.

Dorchester: there are flood risks in the town, mainly confined to the immediate river corridor, and flood incident management is provided in the form of flood warning to properties. There is flood management infrastructure in the town.

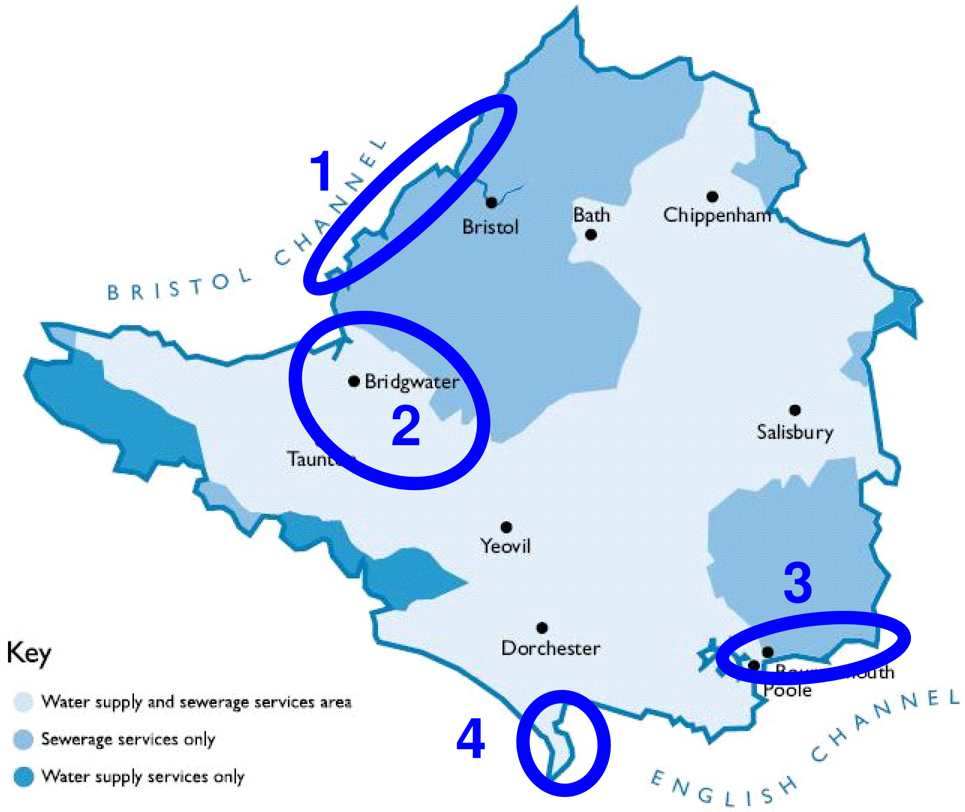
Salisbury: there are flood risks in the town and flood incident management is provided in the form of flood warning to properties. There is flood management infrastructure in the town. Due to the nature of the rivers around Salisbury, they are slow to respond initially but once water levels are raised flood events are sustained and could last many weeks.

Trowbridge: there are flood risks in the town and flood incident management is provided in the form of flood warning to properties and by flood defences. There is also flood management infrastructure in the town.

Yeovil: there are flood risks in the town and flood incident management is provided in the form of flood warning to properties.

http://www.southwest-ra.gov.uk/media/SWRA/RSS%20Documents/Technical%20Documents/Technical%20Work / Flood%20Risk/Final_Regional_Flood_Risk_Appraisal.pdf

<u>**Appendix 2 continued: Regionally significant flood risk areas identified by South West Regional Flood Risk Appraisal (2007)**</u>



	Ground-water	Fluvial	Tidal	Coastal
1		●	●	●
2			●	●
3	●	●	●	●
4			●	●

http://www.southwest-ra.gov.uk/media/SWRA/RSS%20Documents/Technical%20Documents/Technical%20Work/Flood%20Risk/Final_Regional_Flood_Risk_Appraisal.pdf

Appendix 3. Current UKWIR climate change adaptation projects

http://www.ukwir.org/content/default.asp?PageId=65201

2010-11

CL08 Water treatment and climate change
The project aims to assess the impact of climate change on catchment water quality and environmental conditions and the implications that may have for water quality, treatment and treatment processes, optimisation / rationalisation strategies, source protection (quantity and quality) with a view to developing a framework for "no / low regrets", sustainable asset strategies in the context of developing carbon constraints.

CL12 Wastewater treatment and climate change
This project aims to transpose the potential effects of climate change into robustly defined impacts on wastewater treatment processes and services, and seeks to design an appropriate response to those impacts for government, the industry, and its regulators.

Both CL08 and CL12 will look at the potential impact on existing processes and to identify generic sensitivities and thresholds where climate change could have an impact both negative and positive.

2011-12

Impact on climate change on asset management planning
The impact of climate change will affect companies' investment plans. Maintaining the asset performance and customer service will be an issue if like for like replacement continues.

Impact of climate change on source yields
Following publication of UKCP09, UKWIR are working with the Environment Agency on two projects to assess how climate change may affect the supply demand balance. This is a follow on project to develop the detailed methodologies required for water resources and business plans to produce a methodology that can be used to asses the impact of climate change on source yields.

Appendix 4. Adaptation of Montgomery Watson Harza's inventory of climate change risks (for WaterUK, 2007-08)

1. WATER SUPPLY IMPACTS

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
DROUGHT – WATER RESOURCES				
D1	Reduced available supply	reduced security of supply	pressure on water users	8
D2	Higher daily & peak demand for garden watering,	lower security of supply		8
D3	Intake, borehole pump and reservoir draw-off levels do not match reduced levels		service failure	6
D4	Lower river & borehole yields or reduced water quality,	abstraction licences reduced or removed, reducing security of supply		8
D5	Drier conditions	security of supply	increased customer sensitivity to possibility of service failure, affecting security of supply	8
D6	Lower river flows	lower yields, increasing demand on existing storage, reducing in security of supply		12
D7	Lower groundwater levels	reducing borehole yields, reducing security of supply		6
D8	Lower flow rates	deposition; reduced raw water quality		4
D9	River levels fall	reduced reliability as water sources, reducing security of supply		12
DROUGHT – WATER TREATMENT				
D10	Low flows	greater sedimentation & blockages	service failure	2
D11	Reduced raw water volumes reducing dilution		increased drinking water quality risk	12
D12	Intermittency in supply	silt and debris accumulating in service reservoirs and towers	increased drinking water quality risk	12
D13	Intermittency in supply	increased risk of external contaminants entering supply pipelines		3

RS = Risk Score out of 25

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
D14	Loss of supply and de-pressurisation	more frequent pipe failure	contamination of drinking water	3
D15	Inversions in service reservoirs & water towers occur more frequently with low water levels;	cryptosporidium accumulation	increased drinking water quality risk	n/a
D16	Loss of supply and depressurisation of the supply network,	more air blockages	service failure	9
DROUGHT – WATER NETWORKS				
D17	Higher daily & peak demand for garden watering,	increased asset use, faster asset deterioration		3
D18	Loss of / intermittent supply	increased risk of external contaminants entering supply pipelines	contamination of drinking water	3
D19	Loss of supply and depressurisation of the supply network,	more frequent pipe failure	contamination of drinking water	3
D20	Loss of / intermittent supply	increased risk of mechanical asset failure (e.g. in PRVs)	service failure	3
D21	Loss of supply and depressurisation of the supply network,	more air blockages and service failure	service failure	3
D22	Lower flow rates	deposition, reducing raw water quality		2
D23	Loss of / intermittent supply	contamination from accumulated silt and debris being flushed out of service reservoirs and towers	increased drinking water quality risk	12
FLOODING – WATER RESOURCES				
F1	Direct asset flooding	asset loss	service failure	12
F2	More frequent storms and power supply flooding,	power outages	service failure	12
F3	Movement of permanent population (e.g. away from flood plains) and tourism due to flooding,		impacts on demand and security of supply	2
F4	The threat of assets being flooded		higher customer expectations for visible, 'hard-engineered' adaptation solutions	16

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
F5	Increased soil erosion	siltation of dams, accelerating asset deterioration		9
F6	More intense rainfall events & changes to soil conditions	slippage of soil dams, asset loss	service failure, customer flooding	4
F7	More intense rainfall events	overwhelmed spillways, asset loss	service failure, customer flooding	4
F8	More intense rainfall compacting upper soil layers	more run-off, less recharge of aquifers, lower security of supply		3
F9	Flooding	infiltration into pipelines	increased drinking water quality risk	2
F10	More storm water	increased pump usage & accelerated asset deterioration		1
FLOODING – WATER TREATMENT				
F11	Direct asset flooding	asset loss	service failure	12
F12	More frequent storms and power supply flooding,	power outages	service failure	12
F13	More intense rainfall events		discolouration and odour problems for drinking water (through biological consequences)	16
F14	Increased runoff	higher sediment levels	increased drinking water quality risk	16
F15	Direct flooding	contaminants entering underground storage tanks	increased drinking water quality risk	6
F16	Direct flooding	contaminants entering pipelines	increased drinking water quality risk	6
FLOODING – WATER NETWORKS				
F17	Direct asset flooding	asset loss	service failure	16
F17 A	More frequent storms and power supply flooding,	power outages	service failure	12
F18	Flooding	infiltration into pipelines	increased drinking water quality risk	4

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
F19	Direct flooding	contaminants entering pipelines	increased drinking water quality risk	4
F20		contaminants entering underground storage tanks	increased drinking water quality risk	6
GENERAL - WATER TREATMENT & NETWORKS				
G1	Relocation of population from weather, flooding, sea level rise	impacts on supply-demand balance, treatment works, asset capacity etc		3
G2		impacts on supply-demand balance, network capacity etc		3
SEA LEVEL RISE - WATER RESOURCES				
S1	Direct asset flooding, storm damage, coastal erosion or planned retreat	asset loss	service failure	3
S2	Saline intrusion	accelerated asset deterioration		3
S3	Movement of permanent population (e.g. away from flood plains) and tourism due to flooding,		impacts on demand and security of supply	3
S4	Saline intrusion	decreasing yields, causing reduction in security of supply	service failure	3
S5	Tidal limits moving upstream and increasing salinity at intakes,	raw water resource loss and reduced security of supply		3
SEA LEVEL RISE - WATER TREATMENT				
S6	Direct asset flooding, storm damage, coastal erosion or planned retreat	asset loss	service failure	3
S7	Saline intrusion in groundwater	accelerated asset deterioration		3
S8	Sea level rise	increases frequency of power loss	service failure	3
S9	Saline intrusion	decreased yields, causing reduction in security of supply	service failure	3

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
S10	Tidal limits moving upstream and increasing salinity at intakes	raw water resource loss and reduced security of supply		3
SEA LEVEL RISE - WATER NETWORKS				
S11	Direct asset flooding, storm damage, coastal erosion or planned retreat	asset loss	service failure	3
TEMPERATURE INCREASE – WATER RESOURCES				
T1	Higher average and peak temperatures	accelerated deterioration of structures, buildings, machinery, equipment		1
T2	Redistribution of / increase in tourism	reduced security of supply	increased seasonal demand	12
T3	Higher daily and peak domestic and commercial demand	reduced security of supply		12
T4	Higher temperatures and longer growing season	redistribution of / increase in agricultural demand and impacts on security of supply		3
T5	Redistribution of permanent population with warmer conditions,		impacts on demand and security of supply	6
T6	Higher temperatures	reduced security of supply	greater customer sensitivity affecting security of supply	9
T7	Increased evapotranspiration	lower infiltration and borehole yields, reducing security of supply		6
T8		lower surface reservoirs yields; greater reliance on groundwater recharge, reducing security of supply		6
T9		lower infiltration and borehole yields, reducing security of supply		6
TEMPERATURE INCREASE – WATER TREATMENT				
T10	Higher temperatures	more algal growth and micro-organisms in the water supply system	higher drinking water quality risk	20
T11		accelerated deterioration of structures, buildings, machinery, equipment		1
T12		lower raw water quality	increased drinking water quality risk	20

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
T13		impacts on treatment process	improved treated water quality	n/a
T14	More frequent disease that could affect drinking water quality risk	additional potable water standards		1
T15	Higher temperatures		discolouration and odour problems for drinking water (through biological consequences)	20
T16	Increased micro-biological growth	higher risk of residual chlorine depletion, contamination of supplies	increased drinking water quality risk	6
T17		higher risk of residual chlorine depletion, contamination of supplies	increased drinking water quality risk	6
T18	More extreme wetting and drying cycles	greater soil movement, more pipe movement and bursts		6
TEMPERATURE INCREASE – WATER NETWORKS				
T19	Higher average and peak temperatures	accelerated deterioration of structures, buildings, machinery, equipment		1
T20	More extreme wetting and drying cycles	greater soil movement, more pipe movement and bursts		12
T21	Increased micro-biological growth,	higher risk of residual chlorine depletion, contamination of supplies	increased drinking water quality risk	6
T22	Higher peak demand	greater storage requirements to avoid reducing security of supply		6
T23	Increased micro-biological growth	higher risk of residual chlorine depletion, contamination of supplies	increased drinking water quality risk	6

2. WASTE WATER IMPACTS

REF.	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
DROUGHT – WASTE WATER NETWORKS				
D24	Lower precipitation, infiltration & inflow plus water conservation,	lower average and peak flows, resulting in greater sewer deposits and more frequent blockages	customer flooding	16
D25	Lower average and peak flows	settlement in the system, affecting pumping regimes and causing accelerated asset deterioration		2
D26		H2S settlement in the system, causing accelerated asset deterioration		6
D27		settlement in the system; subsequent shock loads causing CSO H&S risk	lower receiving water quality	16
DROUGHT – WASTE WATER TREATMENT				
D28	Change in domestic waste disposal	changes in dry weather flow, pollutants & sewage treatment processes		2
D29	Lower average and minimum sewage flows		lower quality in receiving waters	1
D30	Lower average and peak flows	settlement in the system, affecting pumping regimes and causing accelerated asset deterioration		2
D31		settlement; subsequent shock loads affecting process regimes and accelerating asset deterioration and H&S risk		16
D32		lower volumes received at WWTW and affecting process regime		8
D33		reduced wetting rates at sensitive processes (e.g. trickling filters), increasing need for recirculation pumping		8
D34		longer retention times in settlement tanks; increased septicity / odour problems.		16
D35	Lower river flows & increased seasonal variability,	reduced water quality, leading to tighter discharge standards	increased risk of a consent failure/pollution incident	12
D36	Lower river flows,	effluent required to maintain river flows, reducing flexibility	increased risk of tightening discharge standards	16

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
DROUGHT – SLUDGE				
D37	Change in domestic waste disposal	change in dry weather flow pollutants & composition of sludge		2
D38	More dust	accelerated asset deterioration; impacts on health & safety of staff		3
D39	Changing agricultural practice		changing agricultural demand for sludge	2
D40	Lower water flow	increased concentration of toxic compounds in sludge; affecting sludge reuse and/or incineration		2
FLOODING - WASTE WATER NETWORKS				
F21	Direct asset flooding	asset loss	service failure	12
F22	More frequent storms and power supply flooding,	power outages	service failure	6
F23	Higher rainfall intensities	overwhelmed combined sewers	surface flooding and lower water quality	20
F24	Increased volumes of storm water	combined sewer capacity exceeded	customer flooding	20
F25	Higher groundwater levels	increased infiltration into sewers	customer flooding	15
F26	Increased sewer misuse	blockages	sewer flooding and pollution	9
F27	Increased volumes of storm water	pump capacity exceeded	service failure and reduced receiving water quality at outfall	20
F28	Increased volumes of storm water in combined sewers,	increased pump usage & accelerated asset deterioration		4
F29	Increased volumes of storm water	rising main capacity exceeded, leading to bursts	service failure	2
F30	Higher storm intensity	increased CSO spill frequency	lower receiving water quality	20
F31	Higher winter flows		dilution of spills, reducing impacts on receiving water quality	n/a

REF	PRESSURE...	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
F32	More frequent flooding		higher risk of failing 'spills per bathing season' consents.	20
FLOODING - WASTE WATER TREATMENT				
F33	Direct asset flooding	asset loss	service failure	12
F34	More frequent storms and power supply flooding,	power outages	service failure	9
F35	Longer FFT	impacts on treatment performance	higher risk of consent failure.	6
F36	Increased volumes of storm water in combined sewers,	increased pump usage & accelerated asset deterioration		2
F37	Longer full flow to treatment at sewage treatment works	process regimes affected, accelerating asset deterioration and asset failure		3
F38	More intense rainfall and higher average flows	treatment processes overwhelmed	service failure	3
F39	More dilution / variability in influent flows	process performance efficiency affected		3
F40	Increased flushing effect (from sewer or PST washout)	higher loads to be treated, affecting process performance efficiency	service failure	3
F41	Longer retention of water in storm tanks	increased septicity & odour and affecting process performance efficiency	odour	4
F42	Higher peak levels at discharges	changes to outfall hydraulics and back up pumps	service failure	4
FLOODING – SLUDGE				
F43	Direct asset flooding	asset loss	service failure	6
F44	More frequent storms and power supply flooding,	power outages	service failure	4
F45	Flooding prevents access to fields		service failure	12
F46	Flooding of sludge transport routes		service failure	12

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
F47	Increased runoff from sludge-treated agricultural land		reduced receiving water quality	9
GENERAL - WASTE WATER NETWORKS, WASTE WATER TREATMENT, SLUDGE				
G3	Relocation of population from weather, flooding, sea level rise	impacts on supply-demand balance, network capacity etc		2
G4		impacts on supply-demand balance, treatment type & capacity etc		2
G5		impacts on supply-demand balance, treatment, asset capacity etc		2
SEA LEVEL RISE - WASTE WATER NETWORKS				
S12	Direct asset flooding, storm damage, coastal erosion or planned retreat	asset loss	service failure	6
S13	Saline intrusion	accelerated asset deterioration		4
S14	High rainfall adding to high tides		increased customer flooding; lower receiving water quality	12
S15	Saline intrusion	increased H2S formation in sewers	environmental health risk	4
S16	Saline intrusion	increased corrosion, leading to accelerated asset deterioration		4
S17	Tide locked intermittent discharges	free discharge hindered	customer flooding & lower water quality	9
S18	High rainfall adding to high tides	intermittent discharges affected	reduced receiving water quality	12
SEA LEVEL RISE - WASTE WATER TREATMENT				
S19	Direct asset flooding, storm damage, coastal erosion or planned retreat	asset loss	service failure	12
S20	Saline intrusion	accelerated asset deterioration		6
S21	Higher receiving water levels	increased pumping requirement , causing accelerated asset deterioration		4

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
S22	Saline intrusion	impacts on various aspects of sewage & sludge treatment and asset deterioration, reducing process performance		6
S23	Higher peak levels at discharges	changes to outfall hydraulics and back up pumps	service failure	6
S24	Higher sea levels	dispersion characteristics affected, leading to different classification, tightened consent, & H+S risk		1
SEA LEVEL RISE – SLUDGE				
S25	Direct asset flooding, storm damage, coastal erosion or planned retreat	asset loss	service failure	4
S26	Saline intrusion	accelerated asset deterioration		1
TEMPERATURE INCREASE – WASTE WATER NETWORKS				
T24	Higher average and peak temperatures	accelerated deterioration of structures, buildings, machinery, equipment		1
T25	Higher temperatures	greater microbial action, increased gas production and risk of ignition, endangering staff		2
T26	More extreme wetting and drying cycles	greater soil movement, more pipe movement, accelerated asset deterioration	customer flooding	6
T27	Greater septicity	accelerated asset deterioration and increased odour		9
T28	Greater septicity affecting pumping regimes,	accelerated asset deterioration and increased odour		9
T29	More extreme wetting and drying cycles	greater soil movement, more pipe movement, accelerated asset deterioration	customer flooding	6
T30	Greater septicity	accelerated asset deterioration and increased odour		4
T31		increased toxicity & odour	increased odour and lower receiving water quality	4
TEMPERATURE INCREASE – WASTE WATER TREATMENT				
T32	Higher average and peak temperatures	accelerated deterioration of structures, buildings, machinery, equipment		1

REF	PRESSURE...	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
T33	Higher temperatures	greater microbial action, increased gas production and risk of ignition, endangering staff		2
T34	Higher levels of UV	lower microbe propagation & survivability, affecting treatment process		1
T35	Higher temperatures	increased septicity, reducing treatment performance	higher risk of consent failure	9
T36	Higher temperatures	tighter consents and/or increased H&S risk near discharge points	increased amenity use	6
T37	Greater septicity affecting pumping regimes,	accelerated asset deterioration and increased odour		9
T38	Greater septicity in received sewage	increased odour		16
T39	Effluent standards raised to meet temperature-affected Water Quality Objectives		greater risk of consent failure/pollution incident	12
T40	Higher rate of biological activity,	changing efficiency		n/a
T41	Lower summer flows and reduced freezing frequency	more insect problems		9
T42	Fewer months below critical process temperatures	greater process efficiency		n/a
T43	Greater septicity and need for odour control chemicals,	increased health risks	increased health risks	8
T44	Greater septicity	more undesirable species and fewer normal aerobic heterotrophs, affecting process performance efficiency		6
T45	Greater septicity in sewers / primary tanks,	poor primary settlement and higher secondary treatment loads, affecting process performance efficiency		12
T46	Increased temperatures	lower oxygen transfer efficiency in secondary process, affecting process performance efficiency		8
T47	Greater septicity	increased toxicity & odour	increased odour and lower receiving water quality	1
T48	Warmer water leading to reduced oxygen saturation,		higher risk of a consent failure/pollution incident	2

REF	PRESSURE…	CONSEQUENCE FOR ASSETS & OPERATIONS	CONSEQUENCE FOR SERVICE	RS
TEMPERATURE INCREASE – SLUDGE				
T49	Higher average and peak temperatures		greater incidence of water & wetland associated disease	1
T50	Higher average and peak temperatures	accelerated deterioration of structures, buildings, machinery, equipment		1
T51	Higher average temperatures	less heating requirement for sludge digestion		n/a
T52	Agricultural practice change		agricultural demand for sludge	2
T53	Higher temperatures	odour		16
T54	Higher temperatures	increased insect problems		9

Appendix 5. Framework for assessing risk of climate change impacts

The likelihood **grid** below combines probability (horizontal axis) and time (vertical axis). For example, certain effects of climate change might be unlikely in the next few years but likely in the long term. In this case, the likelihood score would be 2.

	Very unlikely <10%	Unlikely	Too close to call 40% - 60%	Likely	Very likely >90%
Before 2015	1	2	4	5	5
2015 - 2025	1	2	3	4	5
2025 - 2035	1	1	2	3	4
After 2035	1	1	1	2	3

The **consequence grid** below combines the geographic scale of impacts (vertical axis) and the things that are affected (horizontal axis). For example, a drought affecting the whole region, but only affecting assets and not particularly inconveniencing customers or staff would score 3. The same consequence score would be given to a very localised flood which affects a small number of customers. By contrast, a sequence of heavy rain events that causes widespread flooding, placing stress on critical assets and subsequently causing adverse impacts on customers and the environment, would score 5.

	Assets only affected		Assets and staff affected		Assets, staff, customers & environment affected
Widespread, including critical sites	3	4	4	5	5
	2	3	4	4	5
Local & some critical or widespread & non-critical	2	2	3	4	4
	1	2	2	3	4
Localised, no critical sites	1	1	2	2	3

The table below provides a summary of the typical responses that would be required across the consequence scores.

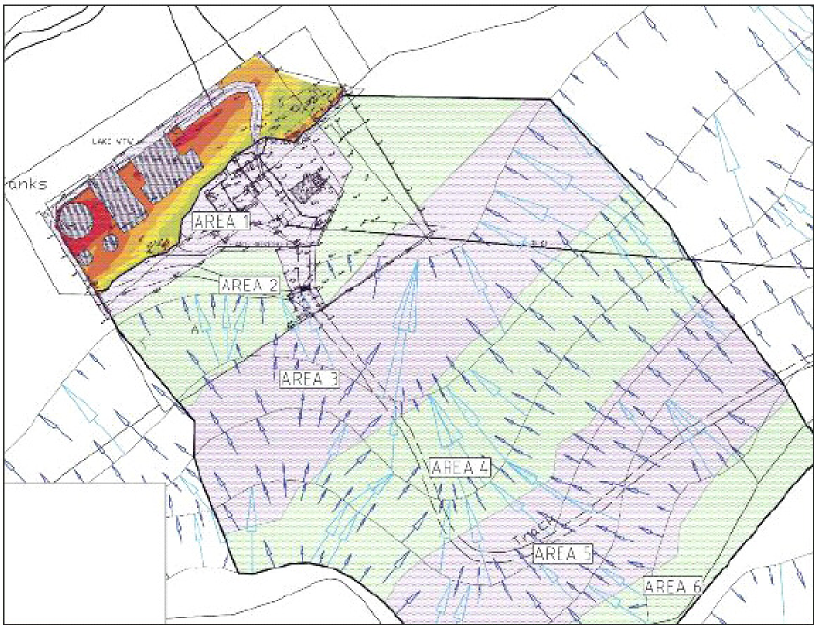
Consequence score	Response, adaptation, mitigation
1	A range of possible responses: a watching brief on local impacts; protection of specific assets to deal with a particular local effect (e.g. flooding from a nearby watercourse); periodic review of performance of assets in the light of gradual change (e.g. warming)
3	Action needs to be taken. In most cases there are already effective solutions, although individual situations might prove to be testing when they arise.
5	Major investment is likely to be needed for reducing the risk. Reactive mitigation would probably be challenging.

Appendix 6. Excerpts from Ofwat (2010) *Climate change – good practice from the 2009 price review*

Page 11 Case studies from the companies' business plans: water service asset resilience

One company, Wessex Water, presented supplementary detail on their asset-level modelling for two water treatment works. The company had carried out detailed flood modelling, and simulated potential flows. It then related these scenarios to the position and characteristics of the asset. The company included the impacts of natural and man-made landforms and structures in its modelling.

In carrying out this work, the company had gone to substantial lengths to understand the risks of extreme weather events. This gave us confidence that it was planning investment based on a detailed understanding of how its assets would perform in such circumstances.



Wessex Water used detailed modelling to understand the risks of extreme events in relation to their assets

Page 13 Case studies from the companies' business plans: sewerage service asset resilience

Sewerage service asset resilience

Wessex Water clearly demonstrated the impact on consumers should the asset fail, as well as the high value consumers placed on avoiding such a failure

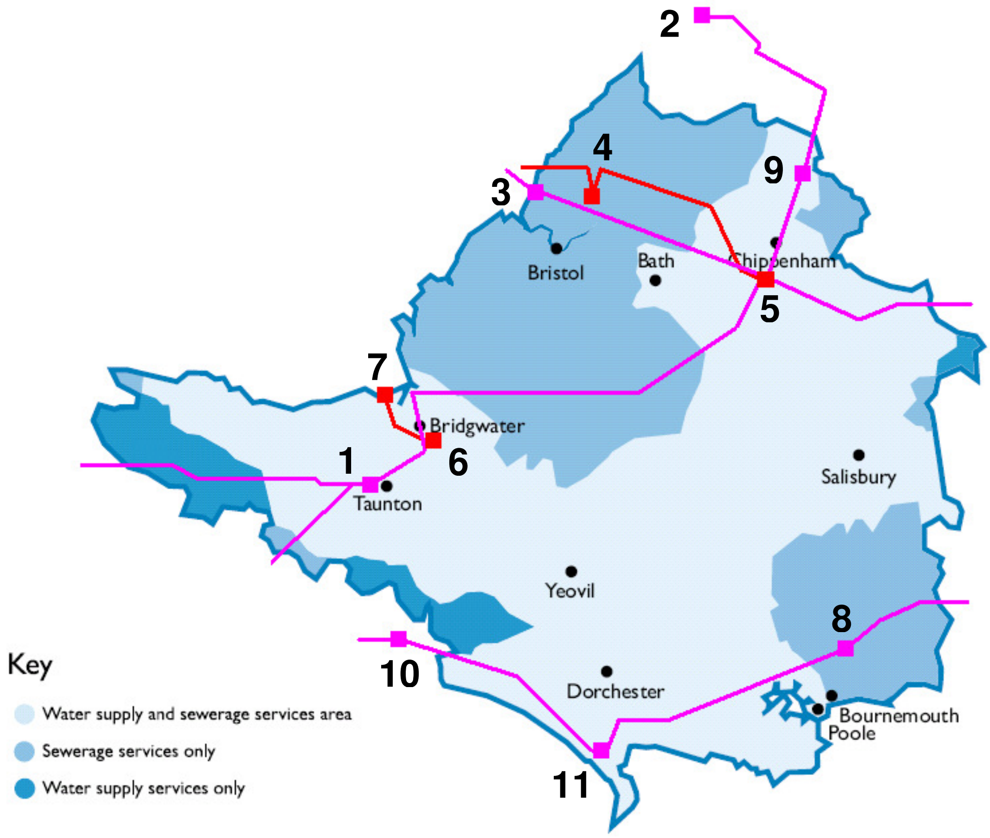
Providing sewerage services to consumers tends to be more resilient than providing water services. Even when sewage treatment works are out of action, the impact on consumers is usually minimal. Similarly, extreme weather events that might be expected to impact on sewerage service assets usually cause pollution problems for other reasons.

The impact on the environment can often be greater after a flood event has subsided, where an asset takes longer to repair. The Environment Agency has concluded that impacts on water quality following the 2007 floods are estimated to have been localised and short-lived. Protecting specific works in these cases is likely to have little effect. This explains why very few companies made convincing cases for investment in this area.

One that did stand out, however, was Wessex Water's case for investment to protect a sewage pumping station from a significant risk of flooding. This was because the company was able to identify a clear impact on consumers if the asset failed. In this case, the asset failing would result in sewer flooding in a town centre, which would affect a significant number of people. The company also gave us evidence that quantified the probability of such a failure occurring.

Consumers place a high value on avoiding internal sewer flooding incidents. Wessex Water was able to demonstrate that its proposal was cost-beneficial and based on customers' willingness to pay, even if the probability of failure was significantly lower than predicted.

Appendix 7. Major substations (400kv & 275 kV)



1. **Taunton**
2. **Walham**
3. **Seabank**
4. **Iron Acton**
5. **Melksham**
6. **Bridgwater**
7. **Hinkley Point**
8. **Mannington**
9. **Minety**
10. **Axminster**
11. **Chickerell**

Source : National Grid website